This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Terrestrial magnetism and atmospheric electricity

Louis Agricola Bauer, John Adam Fleming

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

TERRESTRIAL MAGNETISM
AND
ATMOSPHERIC ELECTRICITY

Digitized by Google

Digitized by Google

TERRESTRIAL MAGNETISM

AND

ATMOSPHERIC ELECTRICITY

AN INTERNATIONAL QUARTERLY JOURNAL

Conducted by

L. A. BAUER,
Coast and Geodetic Survey, Washington, D. C.

With the Assistance of

J. S. AMES
Johns Hopkins University, Baltimore

J. ELSTER and H. GEITEL
Wolfenbüttel, Germany

D. L. HAZARD
Coast and Geodetic Survey, Washington

G. W. LITTLEHALES
Hydrographic Office, Washington

A. McADIE
Weather Bureau, San Francisco

TH. MOUREAUX
Observatoire, Parc St. Maur

H. F. REID
Johns Hopkins University, Baltimore

ADOLF SCHMIDT
Magnetisches Observatorium, Potsdam

L. G. SCHULTZ
C. and G. S. Magnetic Observatory, Cheltenham

A. SCHUSTER
Owens College, Manchester

Foreign Councilors

A. W. RÜCKER
England

W. VON BEZOLD
Germany

E. MASCART
France

M. RYKATCHEW
Russia

VOLUME VII

MARCH–DECEMBER, 1902

THE JOHNS HOPKINS PRESS
BALTIMORE, MARYLAND
1902

Digitized by Google

29871 2

Digitized by Google

CONTRIBUTORS OF ARTICLES AND REVIEWS

R. AMUNDSEN,	Christiania, Norway
S. J. BARNETT,	Stanford University, California
L. A. BAUER,	Washington, District of Columbia
J. C. BEATTIE,	Cape Town, South Africa
KR. BIRKELAND,	Christiania, Norway
G. W. CADY,	Cheltenham, Maryland
C. CHREE,	Richmond, England
C. K. EDMUNDS,	Baltimore, Maryland
J. ELSTER,	Wolfenbüttel, Germany
C. C. FARR,	Christchurch, New Zealand
J. A. FLEMING,	Washington, District of Columbia
N. E. GILBERT,	Geneva, New York
W. HALLOCK,	New York City
K. HAUSSMANN,	Aachen, Germany
D. L. HAZARD,	Washington, District of Columbia
G. HELLMAN,	Berlin, Germany
E. W. HYDE,	Cincinnati, Ohio
E. LEYST,	Moscow, Russia
G. W. LITTLEHALES,	Washington, District of Columbia
F. W. MCNAIR,	Houghton, Michigan
A. MCADIE,	San Francisco, California
J. DE MOIDREY,	Shanghai, China
J. W. MILLER,	Harrisburg, Pennsylvania
M. MORENO Y ANDA,	Tacubaya, Mexico
A. NIPPOLDT,	Potsdam, Germany
G. B. PEGRAM,	New York City
L. G. SCHULTZ,	Cheltenham, Maryland
W. F. WALLIS,	Baldwin, Kansas
F. A. WOLFF, JR.	Washington, District of Columbia

Digitized by Google

TABLE OF CONTENTS

MARCH, 1902

PAGE

PORTRAIT OF PROFESSOR FRANZ EXNER, - - *Frontispiece*, [*Plate I*]

FORTHCOMING ADVANCES IN THE TERRESTRIAL MAGNETISM OF ANTARCTICA, - - - - - - - - *G. W. Littlehales* 1

MESSUNGEN DES ELECTRISCHEN POTENTIALGEFÄLLES AUF SPITZBERGEN UND JUIST, - - - - - - - - - *J. Elster* 9

REPORT ON THE MAGNETIC OBSERVATIONS MADE IN NORTH AMERICA DURING THE TOTAL SOLAR ECLIPSE OF MAY 17–18, 1901, *L. A. Bauer* 16

MAGNETIC OBSERVATIONS MADE AT THE MAGNETIC OBSERVATORY, ZI-KA-WEI, CHINA, DURING PARTIAL SOLAR ECLIPSE, NOVEMBER 11, 1901, - - - - - - - - - - - *J. de Moidrey* 23

LETTERS TO EDITOR: Proposal regarding High Speed Magnetic Observations on International Term Days, - - *C. C. Farr* 26

Reply to above Proposal, - - - - - - *L. A. Bauer* 27

Norwegian Expedition to the Magnetic North Pole, *R. Amundsen* 28

Recent Magnetic Observations in Mexico, *M. Moreno y Anda* 29

BIOGRAPHICAL SKETCH OF FRANZ EXNER, - - - - - - - 31

NOTES, - - - - - - - - - - - - - - - - 32

ABSTRACTS AND REVIEWS: Auroral Light in United States, November, 1901. WEATHER REVIEW. *E. W. Creak*, Determination Magnetic Components on ship. *C. Chree*, Error in Horizontal Intensity due to Flexure of Deflection Bar. *Ekholm and Arrhenius*, On Influence of Moon on Aurora and Thunderstorms. *Chevallier*, Experiments on Influence of Electric Railway Currents, F. A. WOLFF. *F. H. Brown*, Locating Metal Ores. *W. Uljanin*, Results of Magnetic Observations at Kazan, Russia, 1894–1897. *W. Prinz*, Influence of Convection Currents upon Deflections of Delicate Instruments, N. E. GILBERT. *Toepler*, Explanation of Ball Lightning. *F. Linke*, Effect of Vertical Movements of Air on Atmospheric Electricity. *H. Ebert*, Magnetic Measurements in a Balloon, W. G. CADY. *A. Pochettino*, Change in Magnetic Horizontal Intensity with Altitude. *P. T. Passalsky*, Magnetic Anomaly near Iron Mines of Krivoi-Rog, Russia, D. L. HAZARD. *S. C. Hepites*, Magnetic Observations in Roumania in 1898 and 1899, W. F. WALLIS. *H. Arctowski*, Observations of Aurora Australis of Belgian Antarctic Expedition, D. L. HAZARD. The Maguet in Surgery, - - - - - - - - - - - 33–49

RECENT PUBLICATIONS, - - - - - - - - - - - 50

Digitized by Google

JUNE, 1902

PAGE

PORTRAIT OF CHRISTOPHER HANSTEEN, - - *Frontispiece, [Plate II]*

A THEOREM ON FOURIER SERIES, AND ITS APPLICATION IN GEOPHYSICS, - - - - - - - - - - *A. Nippoldt, Jr.* 51

NOTICE OF MAGNETIC DISTURBANCE DURING ERUPTION OF MONT PELÉE, MARTINIQUE, IN MAY, 1902, - - - *L. A. Bauer* 57

UEBER DEN EINFLUSS DER SPIEGEL-COLLIMATION BEI SPITZENAUFHAENGUNG AUF DECLINATIONS-MESSUNGEN, *K. Haussmann* 59

ZUR BIBLIOGRAPHIE VON W. GILBERT'S "DE MAGNETE." *G. Hellmann* 63

PAUL PASSALSKIJ UND SEIN LETZTES ERDMAGNETISCHES WERK, *E. Leyst* 67

BIOGRAPHICAL SKETCH OF CHRISTOPHER HANSTEEN, - - - 75

PROFESSOR MAX ESCHENHAGEN: HIS LIFE AND WORK, *W. G. Cady* 77

THE PROPOSED MAGNETIC RESEARCHES OF THE NORWEGIAN POLAR STATIONS IN 1902–1903, - - - - - - *Kr. Birkeland* 81

NOTES. - - - - - - - - - - - - - - - - 83–85

ABSTRACTS AND REVIEWS: *J. Elster, H. Geitel, C. T. R. Wilson*, Atmospheric Electricity, A. MCADIE. *A. Henry*, Loss of Life in United States by Lightning, A. MCADIE. *F. Exner*, Contribution to Knowledge of Atmospheric Electricity, L. G. SCHULTZ. *A. Zheltukhin*, Influence of Electrical State of Atmosphere on Barometer, L. G. SCHULTZ. *C. Börgen*, Effect of Magnetic Moment and of Distance upon Pol-distance of Magnets, W. HALLOCK. *B. Brunhes and P. David*, Direction of Magnetization in Clay Beds baked by Lava Flows, F. A. WOLFF, JR. *F. A. Chaves*, Magnetic Work in the Azores, J. W. MILLER. *E. Wilson*, Distribution of Magnetism in Rotating Iron Cylinders, C. K. EDMUNDS. *I. St. Murat*, Magnetic Observations in Bucharest in 1899, W. F. WALLIS. *K. Birkeland*, Magnetic Observations and Aurora Borealis in Norway, W. G. CADY. *W. Watson*, Determination of Value of Earth's Magnetic Field in International Units. *V. Carlheim-Gyllensköld*, Magnetic Observations in Spitzbergen in 1898. - - - 86–100

SEPTEMBER, 1902

PORTRAIT OF GENERAL SIR EDWARD SABINE, - *Frontispiece, [Plate III]*

UEBER DIE METEOROLOGISCHE NATUR DER VARIATIONEN DES ERDMAGNETISMUS, - - - - - - - - - *A. Nippoldt* 101

WORK IN TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY IN SOUTH AFRICA, - - - - - - - *J. C. Beattie* 114

WILSON'S GIBBS'S VECTOR ANALYSIS, - - - - *E. W. Hyde* 115

NOTE SUR L'AMPLITUDE DE L'OSCILLATION DIURNE DE LA DÉCLINAISON MAGNÉTIQUE ET SON INÉGALITÉ MENSUELLE, *J. de Moidrey* 125

Digitized by Google

PAGE

NOTE SUR LA VARIATION SÉCULAIRE DE LA DÉCLINAISON À ZI-KA-WEI (CHINE), - - - - - - - - - *J. de Moidrey* 128

BIOGRAPHICAL SKETCH OF GENERAL SIR EDWARD SABINE, F. R. S., K. C. B., - - - - - - - - - - - - - - 131

MAGNETIC DEFLECTION OF LONG STEEL WIRE PLUMB-LINES, *W. Hallock* 141

DIVERGENCE OF LONG PLUMB-LINES AT THE TAMARACK MINE, *F. W. McNair* 143

NOTES, - - - - - - - - - - - - - - - - - 146

ABSTRACTS AND REVIEWS, *G. Murray*, The Antarctic Manual. *N. Yamasaki*, Relation between Seismic and Magnetic Disturbances in Japan. *U. S. Navy*, Protection of Ships Compasses from Electric Currents. *B. Weinstein*, Earth-Current Observations in German Telegraph System, W. G. CADY. *E. Jar*, Earth-Current Experiments. Magnetic Observations at Zi-Ka-Wei, China, 1899, W. F. WALLIS. - - - - - - - - - - - - 148–153

RECENT PUBLICATIONS, - - - - - - - - - - - - 154

DECEMBER, 1902

PORTRAIT OF BENJAMIN FRANKLIN, - - - *Frontispiece*, [*Plate IV*]

RESULTS OF INTERNATIONAL MAGNETIC OBSERVATIONS MADE DURING THE TOTAL SOLAR ECLIPSE OF MAY 18, 1901, INCLUDING RESULTS OBTAINED DURING PREVIOUS TOTAL SOLAR ECLIPSES, *L. A. Bauer* 155–192

RECORDS OF EARTHQUAKES ON QUICKLY-DRIVEN MAGNETOGRAPHS, *C. Coleridge Farr* 193–195

MAGNETIC OBSERVATIONS ON LAND BY THE AUSTRIAN NAVY, BETWEEN 1896 AND 1901, - - - - - - - - - - - - 196–198

LETTER TO EDITOR: MR. WATSON'S COMPARISON AT KEW OBSERVATORY, - - - - - - - - - - - - *C. Chree* 199

NOTES, - - - - - - - - - - - - - - - - 200

ABSTRACTS AND REVIEWS: *H. Ebert*, Magnetic Measurements in a Balloon, W. G. CADY. *F. Linke*, Electric Charge on a Balloon, W. G. CADY. *J. Elster, H. Geitel*, Radio-Activity and Conductivity of the Air, G. B. PEGRAM. *C. Chistoni*, Determination of the Distribution Coefficient, D. L. HAZARD. *F. Richarz, P. Schulze*, Asymmetry in Magnetometer Deflections, S. J. BARNETT. *J. E. Cullum*, Magnetic Observations in Ireland, D. L. HAZARD, - 201–208

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS.

Digitized by Google

Digitized by Google

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VII MARCH 1902 NUMBER 1

FORTHCOMING ADVANCES IN THE TERRESTRIAL MAGNETISM OF ANTARCTICA.

By G. W. Littlehales.

Under the imperial flags of Great Britain and Germany, two co-operating expeditions equipped with exceptional completeness, are penetrating into the high southern latitudes for the advance of knowledge concerning the south polar regions.

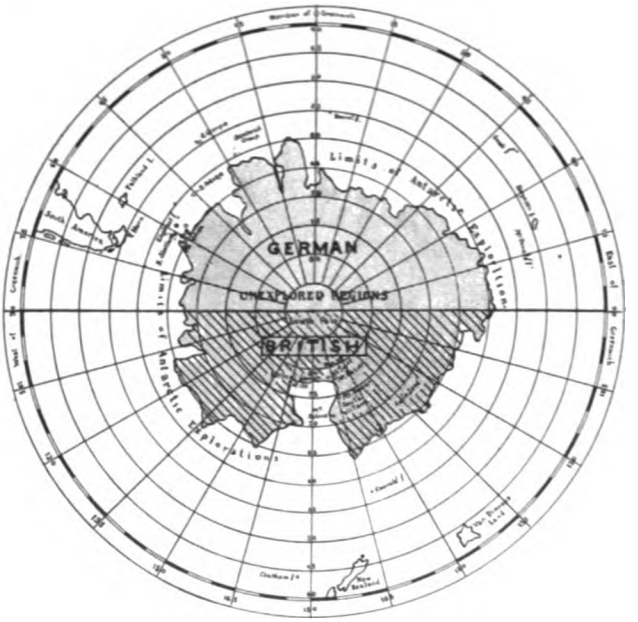
The main purposes are to determine, as far as possible, the extent and nature of the south polar land, to ascertain the nature of its glaciation and the condition of the ice-cap, to observe the condition of the underlying rocks, and to make a magnetic survey south of 40° of south latitude. Much importance is also attached to the meteorological observations, and especially in the regions south of 74° of south latitude. Deep-sea soundings with temperatures are to be taken, and biological observations are likewise to be made. Observations of atmospheric electricity and of polar lights are also provided for in the program.

The German expedition, under the direction of Dr. Erich von Drygalski, Professor in the University of Berlin, will have for its field of investigation the Indo-Atlantic side of the Antarctic region. It has established a base-station at Kerguelen Island, where magnetic and meteorological instruments have been installed for the purpose of keeping a continuous register of meteorological and magnetic phenomena during the time the expedition is engaged in investigations amongst the Antarctic lands. Dr. Karl Luyken, of Düsseldorf, will have charge of the magnetic and meteorological observations at this station. In addition, a base-station is to be established in the Antarctic regions, where, under the direction of

Digitized by Google

Dr. Fr. Bidlingmaier, of Lauffen, magnetic and meteorological observations will be continuously recorded for one year.

The British expedition, under the leadership of Commander Robert F. Scott, of the Royal Navy, has chosen as its base-station, the magnetic observatory at Christchurch, New Zealand, and departing from that place will occupy the Pacific side of the Antarctic regions as its field of investigation. A secondary base-station is to be established, if possible, in Victoria Land. The specialist in terrestrial magnetism of the expedition is Mr. Louis C. Bernachi, F. R. G. S.



ANTARCTIC AREA, SHOWING ALLOTMENTS OF THE TWO EXPEDITIONS.

[For the above map we are indebted to *Knowledge*, June, 1901, issue.]

The program of observations of the two expeditions has been made a subject of international agreement, and has been communicated to all those States which possess magnetic and meteorological stations in order that there may be universal co-operation to secure the ends in view.

Termination Land will probably serve as an objective point for the German expedition, which will sail thence westward to find the

Digitized by Google

west side of Victoria Land, to clear its possible connection with Kemp Land and Enderby Land, and then sail around the Antarctic lands on the Atlantic side.

The British expedition will probably sail eastward from Termination Land to explore the north side of Wilkes Land and then Victoria Land, the Great Ice Barrier, and the Pacific side of Antarctica.

The chief object of each expedition is to establish a scientific station in the south polar region where geophysical investigations may be carried on continuously for a full year, and from which, as a base-station, excursions of a longer or shorter duration can be made for the accomplishment of projected observations.

The endeavor of the Germans will be to plant their station on the western side of Victoria Land, because the extensive land surface which may be looked for there will offer favorable opportunities for scientific investigation. Being near the magnetic pole, magnetic phenomena can be studied to good advantage, and the inland ice of Antarctica can best be ascended and studied where there is an extended land. Perhaps also a journey could be made from there toward the geographical pole. A large extent of land also affords much richer opportunities for studying animal and plant life as well as for geological and gravitational investigations.

To secure the same opportunities, the British expedition will endeavor to land on the east coast of Victoria Land, and will thus be in a position to afford ground for co-operation according to the highest standards of scientific knowledge for the investigation of whatever is characteristic of the Antarctic regions in the domain of terrestrial magnetism, geography, geology, glaciation, meteorology, and other branches of terrestrial physics.

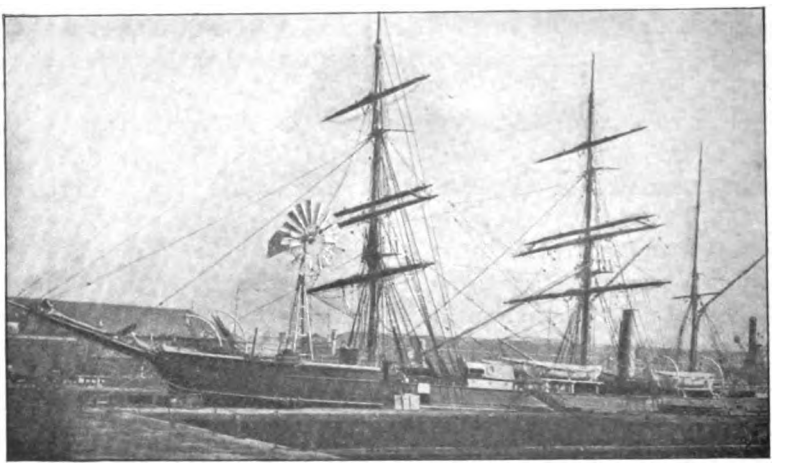
Among the primary objects of both of the expeditions is research in the field of terrestrial magnetism with a view of completing and bringing up to date the magnetic work done by Ross in the *Erebus* and *Terror*, and by Moore and Clerk in the *Pagoda*, about sixty years ago. Since that time no accurate survey of these regions has been made, and, with the ever-changing variation of the needle by unknown amounts, navigation by the compass in the region south of the Cape of Good Hope has become uncertain.

The paramount necessity for securing reliable observations of the declination and inclination of the magnetic needle and of the intensity of the Earth's magnetic force, caused the projectors of the expeditions to design both expeditionary vessels with this special object in view, and it is certain that while at sea both expeditions

Digitized by Google

will determine the magnetic elements each day by the standard compasses of their ships, and the inclination and intensity by the Creak and Fox dip-circles. Absolute measurements of the magnetic elements will be made whenever possible, either on the ice or on the land, and the relative instruments compared with them. For the land purpose a recording magnetograph of the Eschenhagen type will be set up to obtain self-registered records of the variations of the magnetic needle.

The *Discovery* is the name of the vessel in which the British expedition is to set forth. She is built on whaler lines, only with greatly increased strength to withstand the ice pressure, and has a length between perpendiculars of 171 feet, a breadth of beam of 34½ feet, a depth of hold of 17 feet, and a displacement of 1,500 tons.



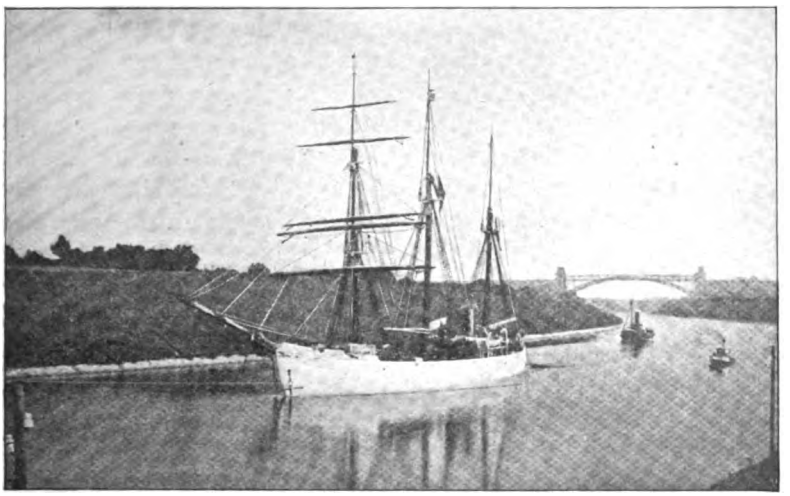
STEAMER "DISCOVERY," SHOWING WINDMILL ON DECK.

Her framing is constructed of Scottish oak, and where she will be subjected to the maximum pressure, heavy transverse bulkheads are supplied. There is a solid mass of wood nine feet in thickness in her stem, while her sides amidships are 2½ feet thick. Her outside planking is of hard wood sheathed with green-heart and iron bark. Owing to the peculiarity of her form, when the ice exerts heavy pressure, instead of crushing the vessel, it will gradually lift her up. She belongs to the auxiliary class of steam vessels, her engines developing only 450 horse-power, and she will

Digitized by Google

thus depend mainly for progress on her sails, with which she is rigged as a bark. She is driven by three propellers fitted with withdrawing shafts and lifting screws, by which means, whenever an exigency arises, the screw shaft can be withdrawn inboard out of the way of the ice. Her boilers are of the best return-tube Scotch type. Her coal capacity is 280 tons, but this is sufficient to carry her 8,000 knots at an average speed of 6½ to 7 knots per hour. She carries a steam dynamo and also a windmill dynamo, for generating the electric current to be utilized in lighting the ship.

The internal arrangements of the vessel are as comfortable as possible. There is the usual range of laboratories and workshops incidental to such expeditions, and roomy quarters for the officers and crew. One prominent feature of the interior equipment is a kind of atmospheric lock by which means the raw Antarctic air is



STEAMER "GAUSS," PASSING THROUGH THE KAISER WILHELM CANAL.

prevented from entering the interior of the vessel when a person enters from the deck. It is a double-door arrangement, and when entering, the person first closes the outer door before he opens the one leading into the apartment. To preserve the warmth of the rooms the walls are lined with asbestos. The stoves are provided with talc doors, having funnel-like fittings over them, through which the air from the outside enters, and is carried over glowing coals to be heated prior to its delivery into the rooms.

To guard against the derangement of the magnetic instruments,

Digitized by Google

upon whose effective use so much of the utility of the expedition depends, the overhead rigging has been made of hemp in all those parts which from their position might introduce magnetic disturbance, and all steel and iron have been excluded from the construction of the vessel within a radius of 30 feet of them.

The German vessel, which is significantly named the *Gauss*, is commanded by Hans Ruser, of Hamburg, a captain in the Hamburg-American line, who was appointed with the Emperor's approval. The *Gauss* is a stanch and seaworthy wooden ship, built to withstand great pressure, but not of the *Fram's* pattern, as the dangers from pressure of ice are thought to be less in the south polar regions than in the north. She has a length between perpendiculars of 151 feet, a breadth of beam of 36 feet, a depth of hold of 16 feet, and a displacement of 1,450 tons. She is rigged as a three-masted topsail schooner, and is provided with auxiliary steam power in the form of a vertical triple-expansion engine of 275 indicated horse-power, which is capable of driving her at a speed of 7 knots per hour. The screw and rudder can be hoisted into a well above them when the conditions of the ice-pressure render it expedient to withdraw them from the water. The best dry oak has been used in her deck beams, and pitch pine sheathed with Demerara greenheart has been employed for the outside planking. The thickness of the ship's sides is 2½ feet.

Amidships, a deck house of teak and fir has been provided to serve as a work-room for the scientific staff. This house is 6½ feet high, and has a length of 25 feet, of which 8 feet is devoted to the purposes of a chart-room and gangway.

On top of the deck house is the captain's bridge, well sheltered by a structure of teak, and provided at each end with oil tanks from which pipes lead to the ship's sides for providing oil to calm the sea in rough weather.

On the bridge is a revolving table for magnetic observations, within a radius of 27 feet of which bronze fittings have been used to the exclusion of iron and steel.

There is another room amidships having a length of about 15 feet, which is mainly used for the storage of instruments, for which purpose it has been designed with extraordinary care.

A photographic darkroom, a drying-room, and a bathroom are also placed amidships, while the kitchen is located between the boiler and engine-room hatches.

Steam heating is furnished to all of the living and working

Digitized by Google

rooms, bath and wash rooms, mess and chart rooms. The heaters are large enough to provide a temperature of +10° Centigrade with an outdoor temperature of −30° Centigrade. In addition to the steam-heating apparatus, iron stoves are provided for the mess-rooms, workrooms, and the passages between the staterooms.

Electric lighting is installed throughout the ship, power being furnished by a dynamo which can be connected with an accumulator battery.

The fuel supply consists of 450 tons of cardiff coal, together with five tons of petroleum and naptha in iron tanks stored on deck.

Besides the two main expeditions related above, there will be one from Sweden, under the leadership of Dr. Otto Nordenskiöld, of Upsala University, and another from Scotland, under the leadership of Mr. Wm. S. Bruce. The ship of the Swedish expedition is the *Antarctic;* the projected route is to Staten Island where the instruments will be compared with those of the magnetic observatory noted below, and thence probably to Graham Land where observations, in accordance with the international program, are to be made for one year.

The Argentine Republic, through the efforts of Dr. Don Francisco Moreno, has established a magnetic observatory on Staten Island.

Recent News Regarding the Expeditions.

The *Antarctic* left Götenburg, Sweden, on October 16th. According to a Reuter message, Professor Nordenskjöld has made the following statement to a Press representative as to the plan and object of his expedition: "From Götenburg we shall proceed to England, and thence to Buenos Ayres and Terra del Fuego, whence we shall make our way to the Antarctic regions. We shall endeavor to push as far south as possible with the *Antarctic;* and, when winter comes on, we shall send a party on shore to winter. That party will probably consist of six persons, of whom I shall be one. We shall build a small hut for ourselves, and engage in meteorological, magnetic, hydrographic, and other scientific observations. As soon as we have landed, the *Antarctic* will return to Terra del Fuego, and a scientific observer, who will sail with her, will conduct the researches in that hitherto little-explored country. In this way we shall be able to work in two detachments, and make as much use of our time as possible. Professor Ohlin, of Lund, and M. K. A. Andersson, will accompany me as zoologists; Dr. Bodman will come as hydrographer and magnetician; M. Skottoburg as botanist, and Dr. E. Ekolof as

Digitized by Google

medical officer. Captain Larsin, who has already made several voyages to South Polar regions, will be in charge of the *Antarctic*."

As the Journal is passing through the press, the following information regarding the English and German expeditions has been obtained: It was part of the instructions of the expedition that the *Discovery* should proceed southwards towards the point of maximum total magnetic force. The dispatches received by the *Times*, state that on November 12, 1901, in latitude 50° S.; longitude 131° E., Captain Scott determined to turn southwards towards this focus, running more or less on the line of no variation. The result was a very gradual increase of total force, while there were other points of interest in the observations of the dip and variation. The *Discovery* continued to push southwards till November 16th, when the first ice was sighted. On November 16th, a sounding was taken in 2,300 fathoms, while the magnetic observations showed a dip of 86°. The farthest south point reached was 62° 50′ in longitude 139° 40′ E. The *Discovery* turned northeastwards on November 17th, and on the 18th a sounding was made in 1,750 fathoms. Captain Scott then made as rapidly as possible for his destination in New Zealand, and Lyttelton was reached on November 28th. The necessary shore magnetic observations were made at the Christchurch Magnetic Observatory. The *Discovery* has since then turned her face southwards to enter upon the real work of the expedition.

The steamer *Miowera* which arrived at Victoria, B. C., on February 21st, from Australia, brought the first reports from the German expedition. The steamer *Tanglin*, which took stores to Kerguelen Island for the German South Polar ship *Gauss*, returned to Sydney before the liner sailed. The *Tanglin* had landed 88 dogs, coal, stores and building material for the *Gauss*, and debarked two of the members of the expedition—Herr Enzensperger and Dr. Luyken, together with three Russian dog tenders.

After a stormy trip, the *Tanglin* arrived off Kerguelen Island, where a landing was made, the German flag run up, and a bottle left, with instructions for the commander of the *Gauss* expedition as to where the stores were to be found. The two gentlemen of the expedition went ashore and located a place for the erection of an observatory. The house erected by the English expedition was still standing, but much out of repair, and it was decided to remove it and erect a new one.

Digitized by Google

MESSUNGEN DES ELECTRISCHEN POTENTIALGEFÄLLES AUF SPITZBERGEN UND JUIST.

Von JULIUS ELSTER.

Im Sommer des Jahres 1900 bot sich mir Gelegenheit, in dem nördlichsten Teile von *West-Spitzbergen* einige luftelectrische Messungen vorzunehmen. Am 5ten August, abends, ging unser Dampfer in dem unter dem 79° N. Br. gelegenen *Virgohafen* vor Anker. Das Wetter am folgenden Tage war schön, der Himmel bis auf vereinzelte Cirri wolkenlos; an der Küste herrschte Windstille, in den freier gelegenen Teilen des Hafens frischte gegen Abend der Wind etwas auf. Als Standort für die Exner'schen luftelectrischen Apparate wählte ich an Land eine frei gelegene Stelle unweit der Trümmer der Andre'schen Ballonhalle. Der Collector befand sich 1.60 m. über dem Erdboden und die Bestimmung der relativen Feuchtigkeit der Luft geschah mittels eines Koppe'schen Haarhygrometers. Es ergaben sich die folgenden Zahlen:

Datum	Zeit	Scalentheil	Volt	Temperatur C.	Relative Feuchtigkeit	Dampfdruck
	h			o	%	
6./VIII. 1900	11½ a	3.6	+100	9.6	72	6.5
	12 m	6.0	+124	8.8	75	6.3
	12¼ p	1.8	+ 50	9.2	71	6.2
	12¾ p	1.8	+ 50	9.0	73	6.3
	1¼ p	2.1	+ 70	8.6	72	6.1
Mittel:			+ 79	9.0	73	6.3

Der Potentialgradient bestimmt sich danach zu 79/1.60 = 49.4 Volt/Meter. Es unterliegt keinem Zweifel, dass diese Zahl nur als eine *untere* Grenze angesehen werden darf, da die Terrainverhältnisse[1] eine zuverlässige Reduction auf die Ebene ausschlossen.

[1] Ein sanft ansteigender, etwa ½ km breiter Strand ist Bergen von 400–500 m Höhe vorgelagert.

Digitized by Google

Mein Bestreben ging nun dahin, auch eine *obere* Grenze dieser Grösse zu gewinnen. Die Möglichkeit hierzu bot sich dadurch, dass etwa in der Mitte des Virgohafen ein Riff die Meeresfläche durchbricht, dessen ziemlich flache Kuppe zu den fraglichen Messungen geeignet erschien. Ich liess mich gegen 5 p. desselben Tages dorthin ausboten und gewann dort folgende Zahlen:

Datum	Zeit	Scalentheil	Volt	Temperatur C.	Relative Feuchtigkeit	Dampfdruck
	h			o	%	
6./VIII. 1900	5 p	20.0	260	9.9	66	6.1
	5⅓ p	9.2	159	7.1	86	6.4
	5¾ p	15.1	227	8.1	84	6.8
	6 p	10.5	172	6.5	81	5.8
	6¼ p	9.0	157	7.2	88	6.7
	6½ p	9.5	162	5.6	100	6.8
Mittel:			190	7.4	84	6.4

Für den Potentialgradienten findet man demnach im Mittel 190/1.60 = 119 Volt/Meter. Diese Zahl liegt bestimmt höher als der wahre Wert. Das Riff steigt nämlich bis etwa 4 m über das Meeresniveau an; die auf seinem Gipfel ermittelten Zahlen müssen daher zu gross ausfallen.

Als Resultat dieser Messungen ergiebt sich demnach, dass an dem genannten Tage das Potentialgefälle in runden Zahlen zwischen 60 und 120 Volt lag, d. h. also etwa innerhalb derselben Grenzen wie in unseren Breiten zur gleichen Jahreszeit.

Am 7ten und 9ten August wurden ebenfalls noch Potentialmessungen ausgeführt; wesentlich höhere Werte ergaben die aus meteorologischen Gründen nicht einwandsfreien Beobachtungen indessen nicht. Am 7ten wurde unter dem 80° N. Br. auf dem Oberdeck des stillliegenden, im Packeise verankerten Dampfers bei Windstille und bedecktem Himmel gemessen und am 9ten auf dem vollkommen ebenen Strande der *Adventbay*. Die letzteren Messungen würden wertvoll geworden sein, wenn nicht bald nach dem Aufbau der Apparate hereinbrechende Regenböen (um 10¼ p.) den Beobachtungen ein Ziel gesetzt hätten. Am 6ten Messungen von 7½ p. bis 9¾ p. vor beginnendem Regen ergab sich für das Potentialgefälle: + 94 Volt/Meter, doch ist diese Zahl aus den angegebenen Gründen unsicher.

Mit den Bestimmungen des Potentialgradienten gingen Hand in Hand Messungen der electrischen Leitfähigkeit der freien Atmo-

Digitized by Google

sphäre. Die arctische Luft zeigte dabei ein electrisches Leitungsvermögen, welches das der über dem continentalen Europa lagernden Luft um das 4 bis 5fache übertraf. Die Vermuthung lag daher nahe, dass der geringe Betrag des Potentialgradienten in Spitzbergen und die hohe electrische Leitfähigkeit reiner Atmosphäre in einem ursächlichen Zusammenhange ständen.

In der That wird man um so höhere Werte des Potentialgefälles erwarten müssen, je kleiner die electrische Leitfähigkeit der Luft, und umgekehrt.

Es schien mir daher von Interesse, die gleichen Messungen wie in Spitzbergen auf einer Insel zu wiederholen, die dem continentalen Europa nahe liegt. Ich entschied mich für die Insel *Juist*, deren weiter ebener Strand zu derartigen Messungen besonders geeignet erschien.

Während nun auf dieser Insel die electrische Leitfähigkeit der Luft sich durchschnittlich nicht höher erwies als auf dem Continente, zeigte das Potentialgefälle dauernd ein ganz abnormes Verhalten. Die Werte waren an klaren Tagen durchgehends so hoch, wie bei uns kaum an den kältesten Frosttagen. Stundenlang anhaltende Maxima von 500–900 Volt kamen häufig vor. Diese hohen Werte liessen sich natürlich nur angenähert ermitteln. Musste doch zur Zeit der Maxima von 4–7 p. das kleinste Ebonitstück des Exner'schen Stativs so tief in den Sand getrieben werden, dass sich die Spitze der als Collektor dienende Flamme nur 8 bis 10 cm über dem Erdboden befand; bei jeder grösseren Höhe schlug das Electroscop durch. Ein isolirter in 1.6 m Höhe aufgestellter Leiter nahm von selber eine positive Ladung an, die sich nach einer Expositions-Zeit von 5–10 Minuten am Exner'schen Electroscop nachweisen liess.

In den ersten Tagen meines vom 7ten bis zum 30ten Juli 1901 währenden Aufenthaltes glaubte ich einer vorübergehenden Anomalie gegenüber zu stehen. Hierin hatte ich mich jedoch getäuscht.

Um den Verlauf der Erscheinung zu kennzeichnen, wähle ich jenen Tag aus, an dem sie am prägnantesten hervortrat, nämlich den 18ten Juli. Der Himmel war wolkenlos und es wehte leichter Nord. Die von 9 a. bis 8 p. ermittelten Werte sind diese:

Zeit:	9a	10a	11a	12m	1p	2p	3p	4p	5p	6p	7p	8p
Potential-gradient:	476	500·	765	720	656	449	561	459	656	800	900	459

Digitized by Google

Ich lasse nun zunächst die Tabelle der Tagesmittel folgen. In dieselbe habe ich jedoch nur die Tage mit geringer Bewölkung aufgenommen, an denen von 7 a. bis 9 p. mindestens fünf Messungen vorlagen.

Datum	Potentialgefälle	Anzahl der Beobachtungen	Temperatur C	Relative Feuchtigkeit	Dampfdruck	Windrichtung	Bemerkungen
			°	%			
10./VII.	+380	10	22.0	66	12.9	N. N. E.	fast windstill.
11./VII.	+370	12	20.6	73	13.0	N. E.	" "
12./VII.	+430	9	22.5	77	15.7	E.	windstill.
16./VII.	+180	5	18.5	89	14.1	W.	fast windstill.
17./VII.	+317	10	21.2	74	13.7	W.	" "
18./VII.	+600	13	19.1	81	13.3	N.	wolkenlos. leichter Wind.
19./VII.	+220	15	20.5	74	13.2	S. E.	" "
20./VII.	+210	10	21.2	89	16.6	E. S. E.	lebhafter Wind.
26./VII.	+200	5	19.5	76	12.7	S. W.	" "
Mittel:	+325		20.6	78	13.9		

Wie man sieht liegen die Tagesmittel ausserordentlich hoch. Tage wie der 12. VII. oder 18. VII. mit einem durchschnittlichen positiven Gefälle von 400 und 600 Volt kommen in Deutschland nur zur Zeit strengster Winterkälte vor.

Das gesammelte Material ist ferner ausreichend die tägliche Variation des Potentials zu bestimmen. Bildet man die Stundenmittel, so ergiebt sich folgende Curve:

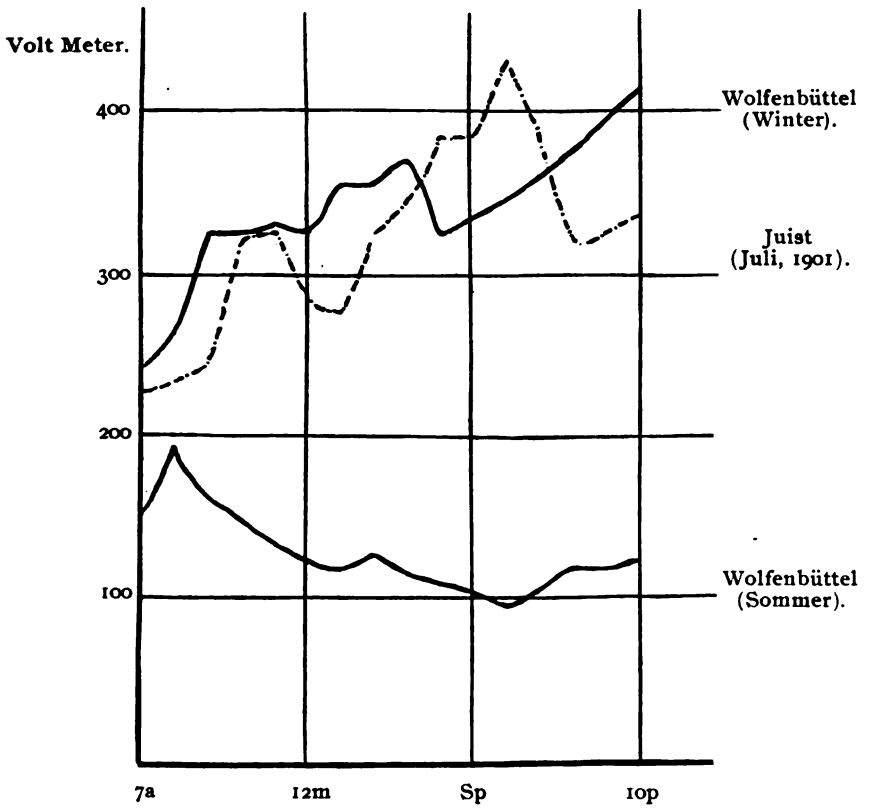
Zeit:	7a	8	9	10	11	12m	1p	2	3	4	5	6	7	8	9p
Anzahl der Beobachtungen:	2	8	8	8	8	8	8	8	8	8	8	8	8	6	5
Potentialgradient:	185	236	245	324	326	288	279	326	345	384	383	431	388	318	324

Digitized by Google

Dieselbe ist in der beigegebenen Figur dargestellt; zum Vergleich wurden die entsprechenden Curven für *Wolfenbüttel*[1] (winterlicher und sommerlicher Verlauf des Potentialgefälles an heiteren Tagen) beigefügt. Wie man erkennt, erreichen die winterlichen durchschnittlichen Maxima des Binnenlandes die zur Sommerzeit auf *Juist* beobachteten nicht.

Die Quelle für den durch obige Beobachtungen nachgewiesenen, anomalen Ueberschuss an freier positiver Electricität in der über *Juist* lagernden Atmosphäre aufzufinden, ist mir nicht gelungen.

Bekanntlich hat *Lenard*[2] gezeigt, dass zerspritzendes Salzwasser die Luft positiv electrisirt. Er zieht hieraus den Schluss und *Lord Kelvin*[3] stimmt ihm darin bei, dass die Brandung der Meeres-



VERLAUF DES POTENTIALGEFÄLLES IN JUIST (JULI, 1901) IM VERGLEICH MIT DEM IN WOLFENBÜTTEL (SOMMER UND WINTER.)

[1] J. ELSTER und H. GEITEL. Wien. Ber. Bd. 51. p. 748. 1892.

[2] P. LENARD. Wied. Ann. 46. p. 584. 1892. "Ueber die Electricität der Wasserfälle." Vergl. S. 631.

[3] LORD KELVIN. On the Electrification of Air. Philosoph. Soc. of Glasgow. 27th March 1895. Vergl. § 12.

Digitized by Google

oberfläche als eine Quelle — wenn auch nicht als die alleinige — für das Vorhandensein freier positiver Electricität in der Atmosphäre angesehen werden muss. Man wird daher geneigt sein, auch den Grund für die auf *Juist* beobachtete Anomalie in der Brandung der Meereswogen zu suchen.

In der That spricht hierfür der Umstand, dass die abnorm hohe positive Electrisirung der Luft bei herrschenden Seewinden besonders scharf hervortritt. So fällt das Maximum der Tagesmittel mit rein nördlicher Windrichtung zusammen; die Winde mit einer Südcomponente, die der Insel z. T. continentale Luftmassen zuführen, drücken dagegen die Werte der Tagesmittel herunter (Vergl. die Beobachtg. von 19, 20 und 26. VII).

Die Thatsache, dass in der Nähe von Wasserfällen die negative Electrisirung der Luft mit Leichtigkeit am Exner'schen Electroscope nachweisbar[1] ist, legt es nahe, analoge Versuche in der Nähe brandender Wogen anzustellen.

Da mir in *Juist* mit den mir zur Disposition stehenden Instrumenten der Nachweis einer positiven Electrisirung der Luft durch einzelne brandende Wogen nicht glückte, so suchte ich in den ersten Tagen des August die weit stärkere Brandung der *Helgoländer* Küste auf und stellte dort einige diesbezügliche Versuche auf der flachen, der Insel vorgelagerten Düne an. Die luftelectrischen Verhältnisse lagen hier ähnlich wie in Juist. Auch hier wurden auf ganz ebenem Strande Potentiale von im Mittel 300 Volt/Meter beobachtet. Dabei war es aber ganz gleichgiltig, ob sich der Flammencollector in 100 m oder 10 m oder ½ m Entfernung von der Brandung befand.

Wäre die Electrisirung durch die Brandung der an Wasserfällen vergleichbar, so hätte jede zerspritzende Meereswoge eine Vergrösserung des Electrometerausschlages bewirken müssen, sobald man den Collector der Woge nur nahe genug brachte. Aber selbst als das Spritzwasser die Lampe des Exner'schen Stativs fast erreichte, war eine messbare Wirkung nicht vorhanden.

Diese Versuche widerlegen natürlich die von *Lenard* und *Lord Kelvin* vertretene Ansicht nicht, denn bei der grossen Zahl brandender Wogen, die den Ocean bedecken, wird immerhin eine nicht unerhebliche positive Electrisirung der über dem Meere lagernden Luftschicht möglich sein, auch wenn die Wirkung jeder einzelnen

[1] J. ELSTER und H. GEITEL. Electrische Beobachtungen auf dem Hohen Sonnblick. Wien. Ber. Bd. 49. p. 1016. 1890 und Notiz über Wasserfallelectricität. Wied. Ann. Bd. 47. p. 496. 1892.

Digitized by Google

Woge nur minimal ist. Gegen diese Auffassung spricht allerdings der Umstand, dass die auf Juist beobachtete Anomalie sicher nicht allgemein verbreitet ist, denn sonst hätte sie bei *Exner's* Messungen an den Küsten der *Adria* und dem Indischen Ocean,[1] sowie bei den oben mitgeteilten Messungen in *Spitzbergen* hervortreten müssen.

Schliesslich darf nicht unerwähnt bleiben, dass die über *Juist* und *Helgoland* lagernde Luft auch ein polarverschiedenes electrisches Leitungsvermögen aufwies. Ein *negativ* geladener und dem electrischen Felde der Erde entzogener Versuchskörper wurde im Mittel 1.3 mal so schnell entladen als ein *positiv* geladener unter gleichen äusseren Bedingungen. Man muss hieraus in Verbindung mit den gleichzeitig beobachteten hohen Werten des Potentialgefälles den Schluss ziehen, dass jene Luft einen abnorm grossen Ueberschuss an freien positiven Ionen enthält.

Bei der grossen Verbreitung, welche die Exner'schen Apparate gefunden haben und bei dem regen Interesse, das luftelectrischen Messungen in neuester Zeit vielfach entgegengebracht wird, giebt die Mittheilung dieser Beobachtungen vielleicht Anlass, sie an geeigneten Orten zu wiederholen.

Sind die Dauer und die Verbreitung der auf *Juist* und *Helgoland* (Düne) beobachteten abnorm hohen Werte des Potentialgefälles erst bekannt, so wird auch die Ergründung der Quelle des ungewöhnlich grossen Ueberschusses an positiven Ionen in den betreffenden Luftschichten mehr Aussicht auf Erfolg haben.

Wolfenbüttel, Januar 1902.

[1] Auf Ceylon hat Exner an Tagen mit starker Brandung zwar einen merklichen Einfluss auf die Angaben des Electroscopes durch den von der Brandung herrührenden Wasserstaub beobachtet; auf hoher See jedoch nicht. Vergl. F. EXNER. Beobachtungen über atmosphärische Electricität in den Tropen. Wien. Berichte, Bd. 98 und 99 (1889 und 1890).

Digitized by Google

REPORT ON THE MAGNETIC OBSERVATIONS MADE IN NORTH AMERICA DURING THE TOTAL SOLAR ECLIPSE OF MAY 17–18, 1901.

By L. A. Bauer.

The following special directions were sent to the field observers of the United States Coast and Geodetic Survey, and to volunteers. It should be recalled, that for this region of the Earth the entire interval was during the night hours, and hence, special precautionary measures had to be taken. It was not deemed advisable to attempt intensity observations, except at the fixed magnetic observatories, for which special instructions fitting each special case were given.

United States Coast and Geodetic Survey.

Washington, D. C., May 9, 1901. *Division of Terrestrial Magnetism.*

DIRECTIONS FOR SPECIAL DECLINATION OBSERVATIONS, on May 17–18, 1901.

a. Make all readings strictly according to 75th meridian mean time, obtaining for this purpose the precise correction on standard time, of the timepiece used, from the telegraphic noon signals, before and after the observations. Mount Magnetometer on a *firm* support, put in good adjustment, and level carefully. Select a primary mark in the horizon that can be read distinctly in the evening and morning twilight, and provide a secondary illuminated mark for night readings, in case these should be necessary. The primary mark should be at least one-fourth of a mile away, and the secondary mark should be not less than 200 yards distant. The distances, in general, should be such, as not to require a changing of focus for distinct vision when pointing on magnet or mark. The angle between the marks must be determined carefully before and after the observations.

b. Provide *non-magnetic* means for illuminating distinctly the scale of magnet. A steady source of light must be used, e. g., a small lamp inclosed in a perforated box made of non-magnetic materials; and it must be far enough away from the instrument so that no disturbing or heating effect results therefrom. The greatest precautions must be taken regarding the possibility of change in the plane of detorsion of the fibers suspending the magnet during the observations. The fibers should be aged, and have their torsion removed as long as possible before the night of the observations, and a reserve supply of torsionless fibers kept on hand in case of emergency. Principal artificial source of change in the torsion to be guarded against during the observations, is from the heating effect of source of illumination, and the glass tube in which the fibers are suspended should, therefore, be screened all around from such a disturbing influence.

c. Azimuth, inclination, and intensity observations should accompany the record whenever possible, the best time for making these observations being left to the observer's convenience.

d. All preparations should be completed on May 16th, civil date, so that the observer may have an opportunity of making some test observations in the

Digitized by Google

evening of that day, and thus satisfy himself as to whether everything will be in good working order on the following night.

e. All care should be taken to exclude artificial disturbing influences of any character during the work—*the same observer making the readings throughout the interval.*

f. Observations are to be recorded as per specimen forwarded, and should be mailed to the Superintendent of the Coast and Geodetic Survey at the earliest possible date, preferably not later than May 21st.

g. For the purpose of taking the temperature readings, suspend thermometer in room or tent, in such a manner, that it can readily be read. If thermometer to magnetometer be used, plug up, air-tight, hole in magnetometer box, through which thermometer is usually inserted.

No.	75th M. M. T.	
1.	7 h P. M. (or before, *not later*) May 17.	Level instrument, etc.
2.		Take two readings of one or both marks, according to circumstances, reading both verniers each time.
3.		Suspend torsion weight in plane of magnetic meridian, and carefully take out all torsion, and record reading of plane of detorsion.
4.		Remove torsion weight, and insert magnet *without letting fibers slacken.*
5.		Set vertical thread of telescope on nearest division to reading of magnetic axis, and read azimuth circle.
6.		Make torsion observations.
7.		Determine magnetic axis, 2 readings scale erect, 4 readings scale inverted, 2 readings scale erect.
8.		Reduce arc of vibration to 1-2 divisions, and take occasional extreme scale readings.
9.	9 h P. M. May 17, until 4 h A. M. May 18.	Take scale readings every minute.
10.	9 h 00 m 30 s to 4 h 00 m 30 s.	Read temperatures every 15 minutes. [Where these readings can not readily be made without disturbing the magnetic work, they should either be omitted entirely, or read only when circumstances make it possible, e. g., before and after the magnetic work, with occasional readings in between. In no case should the magnetic work be allowed to suffer.]
11.	4 h 01 m.	Read azimuth circle.
12.		Determine axis, 2 readings scale erect, 4 readings scale inverted, 2 readings scale erect.
13.		Make torsion observations.

Digitized by Google

No.	75th M. M. T.	
14.		Remove magnet and suspend torsion weight *without letting fibers slacken*, and carefully redetermine plane of detorsion, and record its reading so as to ascertain the amount of torsion developed since beginning work.
15.		Remove torsion weight, and take two readings on mark (or marks) reading both verniers.

The Observer will be interested to know that simultaneous magnetic observations during the proposed interval, will be made all over the globe. He should, therefore, take all needful precautions, that he will be in good physical condition at the time, so that he may secure the highest degree of accuracy.

As stated above, special directions were given to the observers in charge of the magnetic observatories, of which there were but two at that time in the United States, viz., the one at Cheltenham, Maryland, 16 miles southeast of Washington City, and the other at Baldwin, Kansas.

The point upon which great stress was laid in our work, viz., *that there shall be no change of observer during the interval of observation*, was based on the experience gained in May, 1900. A critical examination of the results received from abroad, at places where observers were changed during the interval, has again shown the absolute necessity in close work not to make such changes. In the present instance, to be sure, the long interval, about nine hours, was a severe task for one observer. However, *all* of the Coast and Geodetic Survey observers cheerfully carried out this injunction, although their lot was especially trying, owing to their having the night hours. As in 1900, I again have the pleasure of stating that every one of our observers carried out his work faithfully and conscientiously, and followed rigidly the prescribed directions.

STATIONS OCCUPIED BY THE U. S. COAST AND GEODETIC SURVEY OBSERVERS.

No.	Stations.	Elements Observed.	Observer.
1	Sitka, Alaska	D	S. K. Paul.
2	Baldwin, Mag. Obs'y, Kan.	D and H	W. C. Bauer. S. A. Deel.
2A	Baldwin, Tent Sta., Kan.	D	J. A. Fleming.
3	Little Rock, Arkansas	D	W. Weinrich. W. F. Wallis.
4	Linden, Maryland	D	L. A. Bauer.
5	Gaithersburg, Maryland	D	D. L. Hazard.
6	Cheltenham Mag. Obs'y., Maryland	D. H. Z.	W. G. Cady. J. B. Baylor. H. M. W. Edmonds R. W. Walker.
7	Vieques, I. Porto Rico	D	W. C. Dibrell.

Digitized by Google

The observations at stations Nos. 2A, 3, 4 and 7, were made out in the open air, under tents, and the remainder were made in wooden, non-magnetic structures. At the Baldwin Magnetic Observatory, besides obtaining the regular photographic registrations of D (declination), and H (horizontal intensity), with an Eschenhagen magnetograph, W. C. Bauer made the prescribed declination readings with tangent magnetometer No. 3, inside the absolute house, and J. A. Fleming did the same with sine magnetometer No. 17, out in the open air, under a tent.

The most extensive observations were made at the Cheltenham Magnetic Observatory, under the direction of the Dr. W. G. Cady, observer in charge, to whose scrupulous care and attention to every minute detail, the purpose of the elaborate program of work outlined for this Observatory was successfully accomplished. Namely, at the time of these observations, there were at the Observatory three magnetographs, the old Adie, and two of the Eschenhagen pattern, Nos. 4 and 5, waiting to be tested, and assigned to the projected additional magnetic observatories. The Adie magnetograph (D, H and Z), and the Eschenhagen magnetograph No. 4 (D and H), were arranged for photographic registration of the magnetic variations.

D and H eye-readings were made by Dr. Cady every minute for the entire seven hours interval, with the Adie eye-reading telescopes, and likewise Z readings by Mr. Walker. Eschenhagen magnetograph No. 5 was adapted to eye-reading, and the D and H variations observed by Dr. Edmonds. In addition, Mr. James B. Baylor made declination readings with absolute sine magnetometer No. 8 in the absolute observatory. There were thus obtained simultaneously two sets of photographic registrations, and three sets of eye-readings, with instruments of totally different construction. All necessary observations for determination of base lines, scale values, temperature coefficients, etc., were, of course, also made.

The examination of the various series of the Cheltenham Observatory, and those in the vicinity, showed the superiority of the Eschenhagen magnetograph over the old Adie form, and furthermore, that D eye-readings, with ordinary field magnetometers, if made with care, are equally as good as the best magnetograph results, with the further advantage of the results being immediately available. To get reliable results by photographic registration, it is absolutely essential to have everything in thorough working order as many days before the prescribed interval of observation as possible, to allow the instrument to settle down to a steady-constant condition. Thus, for example, it was necessary to change the quartz fiber suspension in the Eschenhagen eye-reading magnetograph No. 5, on night of May 16th, a day before the prescribed time of observation, and the resulting observations, as compared with those obtained with the other instruments, showed unmistakably a gradual drift in the base line, and a change in the scale value. If, therefore, it becomes necessary to make changes on a magnetograph shortly before its use for a special

Digitized by Google

purpose, observations serving to control any likely instrumental changes during the interval should not be neglected. These matters are mentioned here principally, since a scrutiny of some of the reports received indicate that these necessary precautionary measures were not always taken.

All of the Coast and Geodetic Survey stations were far removed from disturbing influences, as for example, electric cars, with the exception of my own at Linden, Maryland, this station having been selected as my base station for the magnetic survey of Maryland before the advent of the overhead single trolley electric car line in that locality. Linden being situated nearly midway between the Cheltenham Observatory and Gaithersburg, Maryland, where Mr. Hazard observed, a good opportunity was afforded at this time to study the electric-car effects on the declination needle, the line running for part of the way approximately north and south, about one-half mile east of station, and then east and west, about one-tenth mile north of station. The interval of observation was furthermore during a time when the cars were running in full force, and when they ceased entirely.

At one station, Coleman, Texas, occupied by Mr. F. M. Little, the observations failed, because of collapse of tent during a severe wind and rain storm.

In addition to above stations, there were in America five volunteer stations:

Station No. 8—Toronto Magnetic Observatory at Agincourt.

Professor R. F. Stupart, Director, took special care that the self-recording magnetic instruments were in good adjustment, and that they were not disturbed during the eclipse time. Copies of the photographic traces of declination and horizontal intensity were furnished, and the ordinates read by us for every five minutes from 14 h to 21 h, Greenwich mean astronomical time, May 17, and converted into absolute measure with the aid of the data furnished. No correction for change of temperature was applied to the H ordinates, as the temperature was practically constant, and the temperature coefficient practically zero. The traces obtained with this magnetograph (an old Adie), are not very sharp, and were difficult to read accurately. This fact should be borne in mind when comparing the results at Toronto with those at other places.

Station No. 9. El Contadero, Mexico.

Messrs. Valle and Moreno, of the Mexican Observatory, took special pains to co-operate and furnish series of D and H variations.

Station No. 10. Austin, Texas.

Mr. J. M. Kuehne, instructor of physics in the State University of Texas, kindly volunteered his services to make magnetic observations

Digitized by Google

during the prescribed time. His station was located at Austin, Texas, one mile east of the State University, and about 1¼ mile east of an electric-car line, single-trolley ground-return system running north and south, a total length of about three miles, the station being on the side of the road remote from the power-house. He observed some small fluctuations both in declination and in intensity before 12 o'clock p. m., 90th meridian time, which he says give the appearance as if the electric car line were exerting a disturbing influence, observable with their field magnetometers even at that distance. At other times, however, when the cars were running in full force, he has noticed no disturbances.

The declination readings were made by Mr. Kuehne himself, using the Nernst-Edelmann magnetometer, belonging to the State University, and following the prescribed directions as nearly as his instrument would permit. I extract the following from his letter: "A phosphor bronze suspension was used, the torsion weight having been suspended two days before observations were made, and again on the day after; no change in plane of detorsion could be detected. When magnet or torsion weight is removed from suspension, the latter is first clamped, thus keeping fiber stretched and free from torsion. The tripod was firmly set in the ground two days before observations, in order to have it well settled. The telescope was sighted on mark, and the instrument finally leveled about $6^h\,30^m$–7^h p. m., magnet was suspended, and after this the instrument was not touched throughout entire set of readings. Pieces of cardboard were leaned against instrument to shield the magnet and the eyes of the observer from the direct rays of the lamp, which stood on separate tripod, near scale, and about 45–50 cm. from magnet box, to south-southwest. Thermometer was hung from wall of tent, and read after each fifth reading of declination. Increasing scale divisions indicate increasing east declination, the value of ½ mm, scale division being 1.′32. At close of observation, left instrument standing untouched, thinking that the danger of changing the pointing of the telescope was greater than that of changing the torsion on the magnetic axis. At daylight found telescope still set on mark and plane of detorsion unchanged. The times were noted by a watch set by Western Union Telegraph time-signals, the watch losing one second per hour, hence, read one second earlier by watch, each hour during observations."

Besides the declination observations, which I presume were made in a tent, simultaneous horizontal readings were taken, under Mr. Kuehne's direction, in a tent about 25 yards west of the D station, by Mr. Dudley Woodward, Jr., using an experimental intensity variometer, built by Mr. Kuehne. The variometer was set up in a large metal free wooden box under a tent, the instrument being set up and finally adjusted Monday, May 13th.

Digitized by Google

Station No. 11. Ithaca, New York.

The observations at this station were made under the direction of Professor Ernest Merritt, of Cornell University. He writes as follows:

MAGNETIC READINGS FOR SOLAR ECLIPSE VARIATIONS.

"The readings were made on the night of May 17, 1901, and the morning of May 18, 1901, the object being to determine if the solar eclipse had any effect on the Earth's magnetic field. They were taken in conjunction with others, and were therefore carefully timed.

"The instruments used were a galvanometer with a simple non-astatic system suspended with a silk fiber (the instrument was one of the lecture-room galvanometers) and a Kohlrausch Variometer suspended with an aged silk fiber.

"In both cases the field of the instruments was greatly weakened by auxiliary controlling magnets. The readings are therefore much magnified.

"The observations were taken in an unused house far removed from any moving magnetic field such as trolley-cars. During the entire run, the observers remained in their seats, and all magnetic material was left at rest. At 2.00 a. m., one of the observers had occasion to leave the room, thus accounting for the jump at that point. The curve assumes normal form upon his return at 2.03.

"Mr. E. C. Roberts read the Variometer; Mr. Albert Ball the Galvanometer, Mr. W. H. Whitham recorded the readings, and Mr. W. W. Kinsley, Jr., kept the time, read the temperature, and plotted the curve. The curve being plotted at the time of the observations, may be taken as a check on the recorded readings.

"Time was called from the second hand of a watch which had been adjusted to the correct time at noon, Friday. Notice was given five seconds before the time to read, and the readings were taken at the tap of a pencil. The telescopes were as far removed as was possible to allow for the reading of tenths of millimeters on the scale.

"The building in which the instruments were set up was not entirely free from jar, but the observers were careful to keep quiet, so that this source of error was pretty well removed. Silk fibers were used instead of quartz, which we had expected to use until the last moment. The result is, that one of the curves shows indication of torsional effects. I doubt whether the results will be of any use to you, but as I said, it is possible for purposes of comparison, you might find them of value."

[Unfortunately, owing to torsional effects and temperature fluctuations, the observations could not be readily utilized, small variations in horizontal intensity or declination being at times entirely masked by much larger effects apparently due to the reasons stated. L. A. B.]

Station No. 12. Near Boston, Massachusetts.

Under the direction of Professor A. G. Robbins, of the Massachusetts Institute of Technology, declination readings were made at the Institute Geodetic Observatory, by Mr. L. P. Wood, using a tangent magnetometer, loaned by the Coast and Geodetic Survey. The observations were apparently made with care, and in accordance with the prescribed directions. It would seem, however, that there was some constant disturbing influence at work, producing a progressive increase in east declination considerably larger than observed at the magnetic observatories at Toronto and Cheltenham. A change of 1.'3 was also produced by change of observer.

The results obtained at all stations will be given in the résumé of the international observations, which will appear in the next issue.

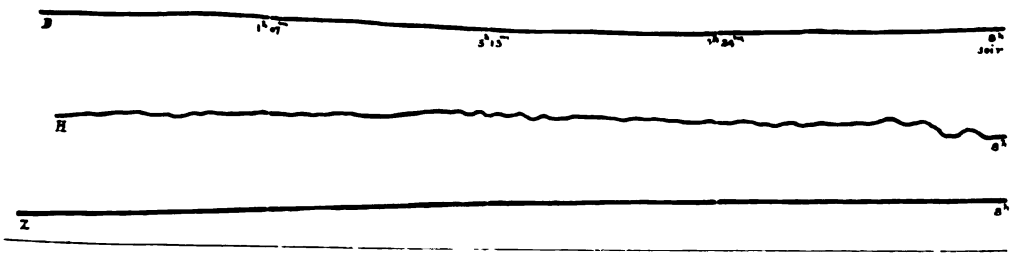
Digitized by Google

MAGNETIC OBSERVATIONS MADE AT THE MAGNETIC OBSERVATORY, ZI-KA-WEI, CHINA, DURING PARTIAL SOLAR ECLIPSE, NOVEMBER 11, 1901.

By J. de Moidrey, S. J., Director.

L'éclipse de soleil du 11 novembre dernier a été visible ici comme éclipse partielle (grande phase 0.616 vers le coucher du soleil). Les observations astronomiques et météorologiques ont présenté peu d'intérêt. Quant à l'étude des effets magnétiques de l'éclipse, la conclusion de notre travail parait bien être négative. Je vous envoie néanmoins nos chiffres dans la pensée que, si on a fait des observations ailleurs, la comparaison pourra être instructive. Le plus intéressant est peut-être la pensée d'utiliser, pour quelques heures, les instruments ordinaires comme variomètres de sensibilité double. La transformation n'est ni coûteuse ni très pénible.

Un balancier battant la demi séconde a été substitué au balancier ordinaire de l'horloge, doublant ainsi les abscisses du temps: on a donné provisoirement à la balance et au bifilaire une sensibilité qu'on ne pourrait leur conserver sans compromettre la stabilité; puis on a fait une graduation avec soin. On avait pour valeur de 1^{mm} sur la photographie: o'.60 pour *D;* 0.000032 c. g. s. pour *H* et 0.000049 pour *Z*.



REPRODUCTION OF MAGNETOGRAM; REDUCTION ONE-HALF.

L'enregistreur a marché dans ces conditions depuis deux heures avant l'éclipse générale jusqu'à une heure et demie après. Pendant ces dix heures, voici la variation de température dans les deux cloches. On voit que nous pouvons compter sur les variations de *H* et *Z*, sans aucune correction de température: c'est une notable incertitude de moins dans les résultats.

Digitized by Google

	h 10	h 1	h 3	h 4	h 6	h 8
Bifilaire	18°.25	18°.22	18°.20	18°.20	18°.22	18°.20
Balance	18°.40	18°.20	18°.20	18°.22	18°.20	18°.20

Voici les lectures des photogrammes, à partir d'un zéro arbitraire. *D* est exprimé en minutes et augmente quand le pôle nord se porte vers l'ouest. *H* et *Z* sont donnés en unités du 6e ordre c. g. s. et augmentent avec l'intensité. Temps moyen de Zi-ka-wei ($8^h\ 5^m\ 43^s$ E. G.).

T	D	H	Z	T	D	H	Z	T	D	H	Z	T	D	H	Z
h m	′	$\frac{1}{10}\gamma$	$\frac{1}{10}\gamma$	h m	′	$\frac{1}{10}\gamma$	$\frac{1}{10}\gamma$	h m	′	$\frac{1}{10}\gamma$	$\frac{1}{10}\gamma$	h m	′	$\frac{1}{10}\gamma$	$\frac{1}{10}\gamma$
11 0	1.75	....	0	20	1.57	160	140	40	0.30	147	245	6 0	0.30	109	270
5	1.82	....	5	25	1.45	170	140	45	0.24	166	245	5	0.30	115	270
10	2.00	109	15	30	1.45	170	145	50	0.24	157	245	10	0.36	102	270
15	2.00	118	15	35	1.39	170	145	55	0.24	154	250	15	0.42	99	270
20	2.00	128	20	40	1.39	173	150	4 0	0.30	160	250	20	0.48	112	270
25	2.06	134	25	45	1.27	173	155	5	0.24	170	255	25	0.42	115	270
30	2.12	141	30	50	1.15	179	165	10	0.18	166	255	30	0.42	115	270
35	2.06	141	35	55	1.09	173	165	15	0.18	170	260	35	0.42	115	275
40	2.12	147	35	2 0	1.15	170	170	20	0.18	163	260	40	0.42	118	275
45	2.12	157	40	5	1.09	160	175	25	0.18	157	265	45	0.42	122	275
50	2.12	160	45	10	0.97	157	180	30	0.18	141	265	50	0.48	125	275
55	2.18	163	50	15	0.85	163	185	35	0.12	150	265	55	0.48	141	275
midi	2.30	154	55	20	0.91	170	190	40	0.06	157	265	7 0	0.48	147	280
5	2.30	138	60	25	0.85	179	190	45	0.00	154	260	5	0.48	115	280
10	2.24	141	65	30	0.79	189	195	50	0.00	150	260	10	0.48	112	280
15	2.24	134	70	35	0.73	205	195	55	0.06	141	265	15	0.48	118	280
20	2.18	141	75	40	0.67	208	200	5 0	0.12	138	265	20	0.48	90	280
25	2.18	154	80	45	0.54	205	205	5	0.18	128	265	25	0.54	32	285
30	2.18	154	85	50	0.48	205	210	10	0.18	115	265	30	0.60	13	285
35	2.06	166	90	55	0.54	205	215	15	0.18	128	265	35	0.73	45	280
40	2.06	163	95	3 0	0.54	189	220	20	0.18	128	265	40	0.79	64	280
45	2.00	157	95	5	0.54	202	225	25	0.18	125	270	45	0.79	32	285
50	2.00	154	100	10	0.54	195	230	30	0.18	122	270	50	0.85	0	285
55	2.00	157	105	15	0.48	189	235	35	0.18	125	270	55	0.91	6	280
1 0	1.94	166	110	20	0.48	192	240	40	0.24	131	270	8 0	0.97	13	280
5	1.88	173	115	25	0.36	189	240	45	0.24	118	270				
10	1.69	170	120	30	0.36	189	240	50	0.30	109	270				
15	1.63	163	130	35	0.30	173	245	55	0.30	96	270				

Il convient de remarquer qu'il y eut, la nuit suivante, une petite perturbation, peu importante, mais bien caractérisée, dont les ondulations des courbes, et surtout de H à partir de 6^h ne paraissent être que les prodromes.

Le décalque ci-joint est en vraie grandeur.

Nous possèdons un autre déclinomètre de variation et un autre bifilaire, tous deux à lecture directe. Les divisions de l'échelle du déclinomètre, qui ont une longueur de 2^{mm} valent 1′.60. Lors qu'il s'agit de lectures à peu près continues, on apprècie bien un vingtième de division càd. en fait les dixièmes de minute.

Quant àu bifilaire, $\frac{dH}{H} = 0.00042$.

Digitized by Google

Un quart d'heure environ avant l'éclipse locale, un aide a commencé à observer les deux instruments toutes les 5 minutes. Il a été remplacé à $4^h\ 15^m$. Le second observateur s'est trompé en lisant H. Il semble bien aussi qu'il y ait une légère différence d'appréciation entre les 2 observateurs: elle expliquerait la variation notable entre $4^h\ 15^m$ et $4^h\ 25^m$.

Voici les lectures, à partir d'un zéro arbitraire.

	D	H		D	H		D		D
h m	′	$\frac{1}{10}\gamma$	h m	′	$\frac{1}{10}\gamma$	h m	′	h m	′
3 30	0.50	49	4 0	0.40	07	4 30	0.10	5 0	0.20
35	0.50	35	5	0.40	07	35	0.10	5	0.20
40	0.40	14	10	0.40	14	40	0.10	10	0.25
45	0.40	14	15	0.40	07	45	0.00	15	0.25
50	0.40	07	20	0.30		50	0.00		
55	0.40	00	25	0.10		55	0.00		

La variation de température n'atteint pas 0°.1. Les observateurs ont noté entre 18°.03 et 18°.07. Aucune correction n'a pas été appliquée.

Enfin, comme renseignement, voici les degrés actinométriques, de cinq en cinq minutes, jusqu'au moment où le soleil n'a plus donné sur les boules. La chute, au moment, de l'éclipse, est bien marquée.

h m		h m		h m	
3 30	39.8	4 0	29.3	4 30	12.2
35	42.0	5	28.2	35	10.5
40	42.0	10	22.1		
45	41.5	15	13.3		
50	36.5	20	18.2		
55	23.8	25			

Si on examine les heures du commencement de l'éclipse générale midi 35^m (temps de Zi-ka-wei), de l'éclipse locale $3^h\ 48^m\ 23^s$, du coucher du soleil $5^h\ 0^m\ 39^s$ et de la fin de l'éclipse générale $6^h\ 33^m$, il parait difficile de trouver, dans les chiffres ou les courbes que nous venons de donner, une anomalie qui puisse être attribuée à l'éclipse. Mais, puisque vous étudiez spécialement cette question, peut-être notre observation offrira-t-elle encore quelque intéret. Je n'ai pas cru utile de calculer avec quelque soin les valeurs absolues: il serait aisé de le faire, si vous le jugiez désirable.

Zi-ka-wei, 12 décembre, 1901.

Digitized by Google

LETTERS TO EDITOR

PROPOSAL REGARDING HIGH SPEED MAGNETIC OBSERVATIONS ON INTERNATIONAL TERM DAYS.

I am sending copies of the following agreement to the Directors of the various Magnetic Observatories. Of course we can not expect the co-operation of those who have been unable to make an arrangement for altering the speed of the magnetograph, and who therefore propose to keep the "term hours" by means of eye-observation. Yet there must be many who have made provision for keeping these hours photographically, and it is to those we especially appeal and ask that they will adopt the high speed, not only for the term hours, but for the complete term day. The extra labor of attending constantly to the magnetograph on these days will not, I think, be raised as an objection, where the days are so few and the issue so great.

I trust you will aid me by giving what publicity you can to the circular.

C. COLERIDGE FARR,

OBSERVATORY CHRISTCHURCH,
NEW ZEALAND, December, 24, 1901.

Circular.

THE OBSERVATORY,
Christchurch, New Zealand,
December 18, 1901.

TO THE DIRECTOR OF OBSERVATORY:

Dear Sir,—As there seems to be some doubt whether circumstances will allow of all the "*term hours*" arranged by the "International Magnetic Co-operation" being kept in the extreme south, and as if so, magnetic records at high speed will be wanting for some of the hours for high latitudes, we have agreed that on "*term days*" we will run the Magnetographs at the Christchurch Observatory and in the extreme south at the high speed during the whole twenty-four hours of the day, thus securing at any rate several complete days' records at the high speed, and yet in no way interfering with the programe already arranged.

Digitized by Google

This will be commenced at Christchurch on the first term day in March, viz., March 1st, and in the extreme south as soon as circumstances will permit, and will be continued in the extreme south as long as possible, and in Christchurch until the British National Antarctic Expedition returns. *Thus the first and fifteenth of every month from* 0 *h. a. m. G. M. T. will be observed as high speed days.*

We trust that if you have made arrangements to run your magnetograph drums at the higher speed (24 cm. per hour), you will see your way to falling in with this suggestion, which we again wish to point out in no way interferes with the international programme, but merely amplifies it.

We are, sir, yours faithfully,

C. COLERIDGE FARR,
In charge Christchurch Magnetic Observatory.

R. F. SCOTT,
Commander British National Antarctic Expedition.

REPLY TO ABOVE PROPOSAL.

In a letter Mr. Farr further explains the reason of above circular. He says:

"Conversations I have had with Captain Scott, have convinced me that it is unlikely he will have a land party during the navigable season, in which case there will be no term hours kept in the south for the summer, and we shall not have high speed records for these hours comparable with those at other places."

Mr. Farr has, of course, in mind only the British Expedition. We as yet have no reason to suppose that the German Expedition will not be able to carry out their program at one or both of their stations.—*cf.* p. 8. The four Coast and Geodetic Survey magnetic observatories are equipped with Eschenhagen magnetographs for which on the high speed (revolution of drum once in two hours) 24 cm. of abcissa equal one hour. Since the beginning of the "term days," the drum was run on the ordinary rate until a few minutes *before* the "term hour," next on the rapid rate until a few minutes *after* the hour, and then on the ordinary rate again, the trace being so arranged that it contained portions, two or more hours on the ordinary rate with the trace on the more rapid rate in between. In addition, eye-readings have been taken during the "term hours," wherever possible.

The advantage to be gained by running on the more rapid rate throughout the entire day, as proposed, is not entirely clear to me. In fact, the necessity of interrupting the trace, even though it be but for a few minutes, every two hours during the day, I fear would, besides entailing a loss of continuous record of ½-1 hour in 24 hours, endanger the strict continuity of the observations. Owing to the frequent presence of the observer in the magnetograph room, slight temperature fluctuations

Digitized by Google

would furthermore be raised and the danger of deranging any part of the magnetograph and interfering with the steady motion of the instrument be materially increased, making it necessary to take frequent eye-readings throughout the day in order to control instrumental changes.

Our experience has thus far been that it is best to have instructions and manipulations as few and as simple as possible and to guard against any risk whatsoever for instrumental changes and disturbances. The result of the elaborate comparisons made at Cheltenham Magnetic Observatory during the night of May [illegible] as related in part, showed furthermore that ordinates for every minute can be read off even on the ordinary speed of the Eschenhagen magnetograph with all the accuracy necessary and attainable with our present photo-magnetic instruments and methods. We therefore do not think it best at present to carry out above proposal.

L. A. Bauer,
Chief of Division of Terrestrial Magnetism
U. S. Coast and Geodetic Survey.

NORWEGIAN EXPEDITION TO THE MAGNETIC NORTH POLE.

MR. ROALD AMUNDSEN the leader of the proposed expedition writes from Christiania under date of January 23, 1902:

"It is my intention to leave Norway in the spring of 1903 and through Lancaster Sound, Bellot Strait to reach the west coast of Boothia Felix. From here I intend trying to relocate the magnetic pole.

"The magnetic instruments which I am going to use are constructed especially for the expedition under the superintendence of Professors Neumayer (Deutsche Seewarte and Chree Kew Observatory). The expedition is equipped for four years."

From this brief statement it is presumed that Mr. Amundsen not only intends determining accurately the location of the magnetic pole by making a detailed local magnetic survey, but also, which is more important to obtain a continuous record of the variations and concomitant phenomena for a considerable period. Modern demands of science would not now be content with such meager data as Sir James Ross was able to furnish in 1831.

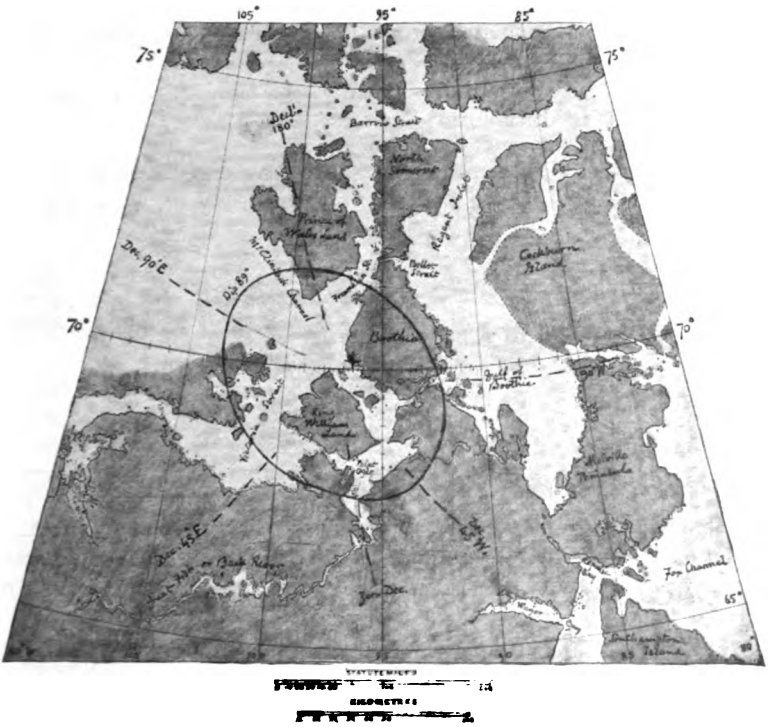
The change in the magnetic inclination—the element principally involved in the location of the pole—along a magnetic meridian, is in this region about 0.8 to 2′ per kilometer. It would furthermore seem that the magnetic pole is at present moving in a northwesterly direction at the rate of about 5.8 kilometers per year.

It would accordingly seem that with our modern instrumental means and methods the location of the magnetic pole defined as the focus of vertical dip and its secular motion, ought to be determinable with

Digitized by Google

sufficient accuracy within the period of the expedition. This pole of vertical dip will likewise be the place of maximum potential—Gauss's definition of the magnetic north pole—if no part of the Earth's magnetism in the polar regions be due to electric currents which pass from the air into the Earth or vice versa. We seem to have some indication that a small part of the Earth's magnetism is of this nature. Mr. Amundsen has doubtless taken this into consideration and will include in his program observations of the electric currents in the atmosphere and in the earth.

Observations ot the diurnal variation of the declination and of magnetic perturbations will be extremely interesting in this region. Owing



ISOCLINICS AND ISOGONICS IN REGION OF MAGNETIC NORTH POLE ACCORDING TO SCHOTT.

to the weakness or practical vanishing of the horizontal directive force of the Earth's permanent magnetism, the declination needle will have its position almost entirely controlled by the horizontal deflecting force of the diurnal variation field and of the disturbance field, and may be made to pass rapidly through all points of the compass back and forth;

Digitized by Google

and needless to say, the observations of polar lights will be extremely important and valuable.

Mr. Amundsen is to be congratulated on the exceptional opportunities before him.—ED.]

SOME RECENT MAGNETIC OBSERVATIONS IN MEXICO.

I take pleasure in forwarding to you a copy of the results of magnetic observations which I made in Zacatlan (Puebla) at the beginning of 1901 and which have not yet been published in Mexico.

The city of Zacatlan is the principal one of the more important districts of the northern region of the State of Puebla, and is situated among the mountains which form the Eastern Sierra Madre, northeast of and at least 200 km. distant from the city of Mexico. Its geographic co-ordinates are:

Latitude 19° 56′, Longitude 1° 08′ E. of Mexico, or 97° 59′ W. of Greenwich, and its altitude, 2030 meters.

1901	Decl'n Obs'd (East)	Decl'n Corrected for Diur. Var'n (East)	Inclination	Intensity in C. & G. S. Units		
				Hor'l	Vert'l	Total
	′	° ′	° ′			
Jan. 29			46 23.3	0.3298	0.3461	0.4881
Feb. 2			22.8	3297	3459	4879
" 6	7°		20.2	3305	3462	4886
" 9	46.5	44.6	21.3			
" 10			20.2			
" 11	48.4	46.9				
" 11	45.5					
" 14	46.2	43.8				
" 14	41.4					
	Mean	7 45.1	46 21.6	0.3300	0.3461	0.4882

The declination on February 9th was observed between 8 and 10 A. M., and on February 11th and 14th, at 8 A. M. and 2 P. M. The inclinations were obtained with needle No. 1. The horizontal intensities were observed between 11 and 12 A. M.

M. MORENO Y ANDA.

Tacubaya, Mexico, October 5, 1901.

Digitized by Google

FRANZ EXNER.

Professor Franz Exner was born in Vienna on March 24, 1849, and in the same city he began his university studies, which were continued and completed in Switzerland and in Germany, where he acted as Professor Kundt's assistant for several years. Later he became docent of physics in the University of Vienna, and was appointed to a professorship in 1879, which position he still holds. He is an active member of the Imperial Academy of Sciences of Vienna.

His first publications treated various subjects, such as the hardness of crystal surfaces, the Sun's radiation, solar photometry, diffusion of gases, etc. These were followed by researches in electricity, mainly on the theory of galvanic batteries, of Volta's fundamental experiment, and of galvanic polarization. His particular efforts were directed towards a revival of the general study of atmospheric electricity, in which he personally took an active part. By the construction of simple portable instruments the extension of such observation over a wider area was made possible and carried out by him in India, Ceylon, and Upper Egypt, as well as in the Alps. To his initiative are also due extensive series of observations conducted under the auspices of the Imperial Academy of Sciences in Vienna, and carried out in Siberia by Dr. Benndorf, and in the form of aeronautic measurements by Dr. Tuma, both of these gentlemen using the method given by Exner, which employs two collectors without connection to the Earth. It is to be hoped that this work, which was of necessity but preliminary in nature, may stimulate systematic observation of atmospheric electricity in a much larger number of places.

Within recent years Professor Exner, turning his activity to the domain of optics, has measured, jointly with Dr. Haschek, the spark-spectra of all the elements by means of a large Rowland grating. All these measurements having been executed under identical and well-defined conditions, and with great accuracy, a table of wave-lengths of all these lines (about 50000 in the ultra-violet) has resulted, which will doubtless be found of great value to investigators in spectral analysis.

Nearly all of Exner's investigations have been published in the transactions of the Imperial Academy of Sciences.

Digitized by Google

NOTES

1. *J. Elster and H. Geitel* were awarded on June 1, 1901, by the Vienna Academy of Sciences, the Baumgartner prize.

2. *Corrigendum.* In the Biographical sketch of von Bezold (Vol. VI, p. 144), the 13th line, read that he was appointed professor *extraordinarius* at the "Technische Hochschule" at Munich in 1866 and *ordinarius* in 1868, instead of *extraordinarius* in 1868.

3. *Magnetic Observatory in Samoan Islands.* Owing to the withdrawal of Mr. Nippoldt from the directorship of this observatory (see Vol. VI, p. 201), its establishment has been considerably delayed. Dr. Tetens, first assistant at the Strasburg Observatory has now been given charge, but he will be unable to leave Europe before April 1st, and it is hardly expected that the Samoan Observatory will be able to take part in the international work before June 1st.

4. *Method to determime position of a balloon.* M. MOUREAUX, at the meeting of the Permanent International Aeronautical Committee of July 18, 1901, proposed a method for determining the geographical position of a balloon by observations of declination and dip, the time required for which being about 30 seconds. By comparing the balloon results with his magnetic charts of France, the variation of the magnetic elements for the small altitude under consideration being neglible, the position of the balloon within 25 kilometers could be ascertained.

5. *Magnetic Observations along the coasts of Indo-China.* Under the order of the French Minister of Marine, an expedition was expected to leave Marseilles for Indo-China early in January, to be under the command of LIEUTENANT HÈRON. Besides making an accurate survey of the coast, hydrographic investigations, etc., it is the intention to determine the magnetic elements at a sufficient number of points to determine their distribution.

6. *Valeurs des principaux éléments du magnétisme terrestre, à Zi-ka-wei, près Changhai, Chine, le 1 Janvier, 1901.*

Si on prend pour le 1 janvier, la moyenne de toutes les observations horaires de décembre et de janvier, on trouve comme valeurs absolues des principaux éléments magnétiques, à Zi-ka-wei, le 1 janvier, 1901.

$D =$ 2° 23′.01 W.	$X =$ 0.32843 c. g. s,
$I =$ 45° 42′.19	$Y =$ 0.01366
$H =$ 0.32872 c. g. s.	$Z =$ 0.33689
	$W =$ 0.47069

Oscillation diurne de D, 1′.96.
Heure du minimum de D, 10 h 6 m.
Heure du maximum de D, 13 h 22 m.

Zi-ka-wei, 31 décembre, 1901. J. DEMOIDREY, S. J.

Digitized by Google

ABSTRACTS AND REVIEWS

AURORAL LIGHT IN THE UNITED STATES OF NORTH AMERICA, NOVEMBER, 1901.

The following extracts are from the Climate and Crop Section Reports of the United States Weather Bureau, November, 1901:

Laporte, Indiana.—About 5.30 P. M., on the 28th, the observer noticed a peculiar light in the western heavens. The sky was covered with broken clouds through which the light shone.

Huntington, Indiana.—A peculiar streak of light was observed in the northwest about 6 P. M. on the 28th.

Staffenville, Lewis County, Missouri.—An aurora observed on the 28th.

The aurora borealis appears in every form, from the most magnificent display to the most insignificant patches of light that appear for a few minutes and then fade away forever. The above phenomena may well have been of the latter auroral character. Laporte, Indiana, is from 50 to 75 miles northwest of Huntington. A northeast wind had been blowing from out an area of high pressure; the sky was covered with cumulo-stratus clouds at Laporte, but was probably clear at Huntington. These are the conditions that generally accompany auroras, and we may assume that there was a faint one on the present occasion, although it was not observed elsewhere in the United States or in Canada.—*C. A. in Monthly Weather Review, p. 512, November, 1901.*

DETERMINATION OF THE COMPONENTS OF MAGNETIC FORCE ON BOARD SHIP.[1]

The two instruments constructed a year ago, according to Captain Creak's design, and described below, were tested at Kew and found satisfactory. They are now on board the *Discovery*. A third instrument was ordered for use on board the German Antarctic ship *Gauss*, and a fourth has since been constructed and was exhibited at the Glasgow meeting of the Association.

On a New Form of Instrument for Observing the Magnetic Dip and Intensity on Board Ship at Sea.[2] *By* Captain E. W. CREAK, *C. B., R. N., F. R. S.*

One of the principal objects of the Antarctic expedition which sailed last month in the *Discovery* is to make as complete a magnetic survey of the regions south of the fortieth parallel of south latitude as possible.

As the greater portion of that region is open sea, it is obvious that, with

[1] Report of the Committee of the British Association for the Advancement of Science, Glasgow, 1901, consisting of Professor A. W. RÜCKER (Chairman), Dr. C. H. LEES (Secretary), Lord KELVIN, Professor A. SCHUSTER, Captain E. W. CREAK, Professor W. STROUD, Mr. C. VERNON BOYS, and Mr. W. WATSON.

[2] For additional description of instrument, with illustrations, see T. M., Vol. VI, p. 119.—ED.

Digitized by Google

few chances of landing, the major portion of the survey must be conducted on board ship.

Previous experience in H. M. S. ships *Erebus* and *Terror* in 1839–43 (both wooden sailing ships) showed the serious effects of the iron in those ships in disturbing the magnetic instruments established on board. In the case of the *Discovery*, with engines, boilers, and numerous other iron bodies on board, magnetic observations would have been almost impossible but for the precautions of first choosing a place for the magnetic observatory in the ship and then insuring that no iron of any kind should be allowed to be placed within a thirty-foot radius from that position.

The ship having thus been prepared, the important question of a reliable instrument for observing the magnetic dip and total force on board of her arose. The only instrument hitherto used for this purpose has been Mr. R. W. Fox's dip and intensity apparatus invented in 1835, and little or no advance made in its construction since then. It certainly did valuable work in the Antarctic Magnetic Survey carried out in the *Erebus* and *Terror* under Sir James Ross, and also in the *Challenger* expedition of 1872–76. An examination of the work done in the *Challenger* under most favorable circumstances disclosed certain defects of a character which are quite inconsistent with the precision now required.

For example, the needles could not be reversed, and hence there was constant necessity for frequent comparisons with an absolute instrument on land to obtain index errors. The magnetic moments of the needles were liable to change, with no accurate means of knowing when the change took place, thus vitiating the sea observations of total force made by the method of a constant deflecting weight. Again the deflecting magnets used for a second method of obtaining the total force were liable to changes, with no means for ascertaining the period of such change at sea. The Fox instrument was therefore not suited for the purposes in view.

Previous experience having shown me the excellent values of the absolute horizontal force to be obtained with the Barrow's Dip Circle fitted with Lloyd's needles, especially in high latitudes, I arranged for a series of experiments to ascertain the best methods of applying the principles of Lloyd's method to an instrument which could be used on a gimbal table on board ship. The use of needles with cylindrical axles resting on agate planes, either for dip or force, was impossible, and trials with various forms of needles and jewels resulted in my adopting the forms for both in the instrument exhibited. All the needles have axles terminating in a cone with a sharp point rounded off and highly polished. The jewels are highly polished sapphires fixed to the cross bars of the circle in which conical cavities, slightly larger than the axles of the needles, have been drilled and polished. The upper half of the jewel is removed, thus leaving a cup into which the axles of the needle can be lowered by the lifter provided. By this arrangement the needles can be retained in place even when the gimbal table, upon which the instrument is placed, is subject to irregular motions, due to those of the ship.

With the circle thus fitted the absolute dip and total force can be observed agreeably with the usual methods described in the "Admiralty Manual of Scientific Enquiry."

As there might be a slight oscillation of the needle at times when the ship

Digitized by Google

is unsteady in a seaway, I have arranged that the ends of the needles shall come so near the graduated arc that the readings may be made directly by the microscopes without the use of verniers, as in the land instruments.

To obviate friction between the axles of the needles and the jewels I have fitted a knob on the top of the circle, which should be gently rubbed with a circular motion of the ivory rubber provided.

The readings of the circle may be accurately made at night by placing a candle at the back of the circle when the light will be reflected by the ivory faces of the microscopes to the graduated arc.

The zero of the graduations on the base plate is so placed that whenever the magnetic direction of the ship's head is known by a compass adjacent the plane of the circle can be immediately placed in the magnetic meridian without the trouble of finding the meridian by the usual method with the circle.

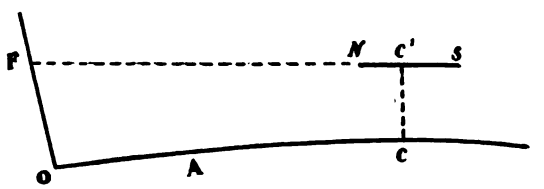
Two instruments of the kind described are now in use in the Antarctic ship *Discovery*, and the German expedition in the Antarctic ship *Gauss* have also one with two sets of needles.[1]

ERROR IN HORIZONTAL INTENSITY DUE TO FLEXURE OF DEFLECTION BAR.

By C. Chree.

Applications of Elastic Solids to Metrology. Sections 36 and 37, Application to Deflection Bars of Magnetometers. Repr. *Proc. Phys. Soc. of London*, Vol. XVII; also *Phil. Mag.*, Nov. and December, 1901.

In A, B, B', and C it is the length of the bar itself that has to be considered. D and E are representatives of a different class. They serve to support a carriage holding a magnet The carriage may have a groove fitting on the bar, or a projecting pin fitting in one of the series of holes in the upper surface. In either case, supposing the adjustment perfect and the bar strictly horizontal, the center of the magnet—which is the



fundamental point—will be vertically over a certain graduation on the bar, and at a constant height h above the neutral plane. In actual use, however, the bar bends under its own weight and that of the magnet and carriage combined. This is illustrated diagrammatically in the fig-

[1] A similar instrument is being made for the United States Coast and Geodetic Survey.—Ed.

Digitized by Google

ure, supposed to be a vertical section containing the magnetic axis NS and the line of centers OAC of the bar. The arrangements are such that NS is parallel to the tangent at C, while the normal at C passes through C^1 the center of the magnet. F in the figure represents the center of a second magnet whose suspension is vertically over O, and whose height is altered until F appears central, as seen through a sighting-tube temporarily substituted for NS. The magnetic reductions suppose NS horizontal, in the same horizontal plane with F, and at a distance from it equal to OAC, or c. In reality NS is inclined to the horizon at an angle $\tan^{-1}\frac{dy}{dx}_{x=c}$; and if we suppose—which is not strictly true—that the sighting-tube is as heavy as the magnet, the true distance of C^1 from F is not c, but

$$c\left[1+\tfrac{1}{2}\left(\frac{dy}{dx}_{x=c}\right)^2\right]+h\left(\frac{dy}{dx}_{x=c}\right)$$

The bar D rests throughout its central 29 cms. on a horizontal plate, to which it is bolted at two points each 14 cm. from the center. Thus the half on one side of the center is practically a rod of 61 —14, or 47 cms. length, clamped at one end so that y and dy/dx vanish with x. The bending and stretching are thus the same as in the half of a bar 94 cms. long supported at its center.

The bar E rests on horizontal pins which pass through two holes drilled through the bar at the level of its neutral line. It may thus be regarded as supported, the distance of the supports from the center being half the distance (6 cms.) between the pins. Consequently for E we have $l=45$, $a=3$. The magnet with its carriage weighs approximately 122 grammes in the case of D, and 390 grammes in the case of E.

Commonly the magnet is used at two fixed distances, its center being either 30 or 40 cms. from the center of the bar. What we want to know in the present case is the slope at the particular point where the additional weight acts. As already explained, this is the precise point where the Bernoulli-Euler results are likely to be least exact; still, the uncertainty is hardly likely to be serious. Employing the value given for ω, etc., in Table I, I find the following data for the slope and for the quantities on which the distance C^1F in the figure depends:

	Bar D.		Bar E.	
Magnet at	30 cm.	40 cm.	30 cm.	40 cm.
Angle of slope of magnet =	78″	113″	115″	163″
$h\,dy/dx$ (cms.) =	.00189	.00273	.00379	.00537
$\frac{1}{2}c\,(dy/dx)^2$ (cms.) =	2×10^{-6}	6×10^{-6}	5×10^{-6}	13×10^{-6}

So far as concerns the effect on the magnetic observations, the departure of the magnetic axis from horizontality is negligible, and the value of $(c/2)\,(dy/dx)^2$ is wholly insignificant. It is otherwise, however, with $h\,dy/dx$, especially in the case of the bar E, where the error introduced is almost exactly twice as great as with D. In both bars the

Digitized by Google

value of $h\,dy/dx$ varies pretty closely at the distance c. This is so far fortunate, as it minimizes the indirect effect on a certain correction supplied by magnetic theory, whose accuracy is sensitive to errors in the assumed values of the distances between the deflecting and deflected magnets. To calculate the direct effect on the calculated value X of the horizontal magnetic component we may employ the formula:

$$X^2 = \frac{N}{r^3}$$

where N is a function of certain observed quantities, including time of vibration and sine of deflection-angle, while r is the distance between the centers of the two magnets. The correction δX to X, necessitated by a correction δr to the received value of r, is given by

$$2\frac{\delta X}{X} = -3\frac{\delta r}{r}$$

For bar E, on the average of the results at 30 and 40 cms.,

we have $$\frac{\delta r}{r} = +\ 0.00013,$$

whence $$\frac{\delta x}{X} = -\ 0.000195.$$

At London, where $X = .184$ c. g. s. approximately at present, this would give $\delta X = -\ .000036$ c. g. s.

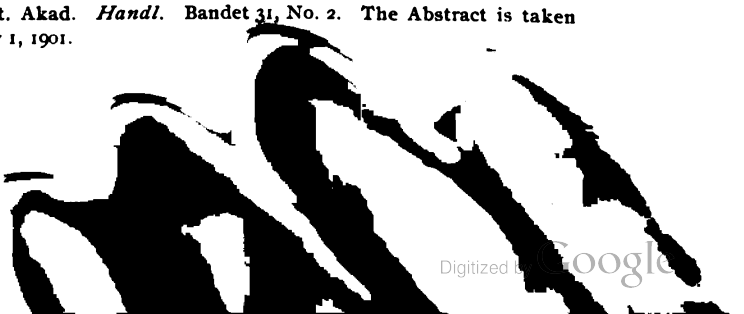
Near the magnetic equator—*e. g.*, in parts of India—X is twice as large as in London, so that the *error* introduced by the flexure of bar E under gravity might attain to $+\ .00007$ c. g. s. As it is usual to attempt to measure X—or at least to record its value—to .00001 c. g. s., the source of error now indicated possesses more than merely theoretical interest.

EKHOLM AND ARRHENIUS:—ON THE INFLUENCE OF THE MOON ON THE AURORA AND THUNDERSTORMS.[1]

The authors, in two earlier papers, proved the existence of a monthly variation in the fall of potential of atmospheric electricity, according to the tropical lunar revolution. In the present investigation, they show the influence of the moon also on the other electric phenomena of the atmosphere —the aurora and thunderstorms.

If the phenomena of the aurora be arranged according to the days of the synodic month, there always appears a well-defined periodicity, with a maximum at new moon and a minimum at full moon, the former being 2–5 times as intense as the latter. As, however, this periodicity is, partly at least, caused by the influence of the moon's light—during full moon feeble aurora can not be observed—it was necessary to eliminate this influence. This was effected in two ways. By the first, the greatest number of the synodic period

[1] Kong. Svenska Vet. Akad. *Handl.* Bandet 31, No. 2. The Abstract is taken from *Climat* No. 4, May 1, 1901.



Digitized by Google

is divided by all the rest, and by the quotients so obtained all the observations, according to the order in the synodic month, are multiplied. The series of observations, thus treated, is freed from the influence of the moon's light. The second method results from the relation existing among the tropical solar year ($Y = 365.2422$ days), the tropical month ($T = 27.32$ days), and the synodic month ($S = 29.53$ days), viz.: $13.36827\ T = 12.36827\ S = J$.

By analogy, a new period (U) may be assumed, in which the moon's light exercises the same influence on the frequency of the aurora as in the tropical month. For, if we suppose: $11.36827\ U = 12.36827\ S - J$; $U = 32.12821$ days.

The vernal equinox is taken as the beginning of the period.

In the period U, the days being read backwards, the full moon begins in the same phase in the same time of the year as in the period T, and therefore the moon's light exerts the same influence in both periods. As, in the period T, a day is $\frac{1}{27}$, while, in the period U, it is $\frac{1}{32}$ of the length of the period, it follows that $1\frac{5}{27}$ of a day in U corresponds to 1 day in T, and therefore the period U can be so transformed that the variation caused by the moon's light in U will be identical with that in T.

Hence, the period U thus transformed will truly represent the effect of the moon's light on the visibility of the aurora. To eliminate this effect, we subtract each member of the period U so transformed from the corresponding member of the period T; the differences so obtained represent the true period of the aurora according to the tropical month. The first method will diminish the true periodicity of the aurora according to the tropical monthly period; the second probably gives the correction for the moon's light very nearly right.

To eliminate the disturbing influence of the tropical month period on the synodic (in the investigation of the synodic month period of thunderstorms) the authors calculated analogously to the period U a period V, in which $14.36827\ V = 13.36827\ T = 12.36827\ S = J$; therefore $V = 25.42006$ days.

The days of the period V have the same properties in relation to the period S as those of the period U to the period T, and with their help the synodic month period of thunderstorms can be truly represented.

The material for the investigation of the tropical period of the aurora consisted of the observations on the aurora in Sweden, Norway, Iceland and Greenland, North America, and the southern hemisphere.

After all observations had been arranged according to the tropical month and synodic month period and the influence of the moon's light in the former period eliminated by the two methods of reduction, the following results were obtained:

The aurora everywhere shows a very pronounced periodical variation with the declination of the moon in the northern hemisphere, the intensity of the light developed containing its maximum in the neighborhood of the southern lunistice, and its minimum in that of the northern, the reverse being the case in the southern hemisphere. This period is of the same nature in the summer half year as in the winter, although the effect of the moon's light on the visibility of the aurora in these two seasons tends to cause opposite periods, as the full moon in summer in the northern hemisphere occurs in southern declination, in winter in northern.

Digitized by Google

The relative intensity of the aurora, as a percentage or the mean, is found by the second method to be:

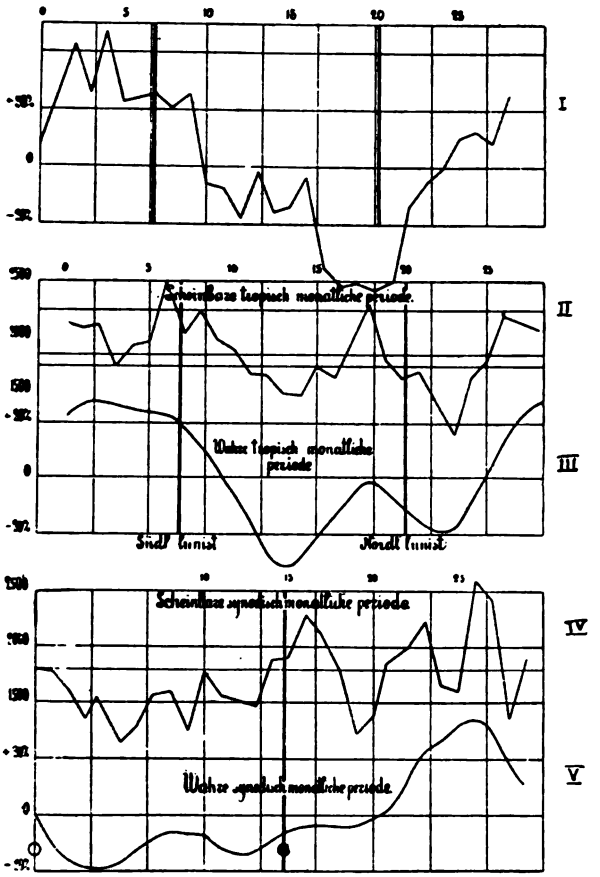
NUMBER OF OBSERVATIONS.[1]

	Near Northern Lunar Tropic	Near Southern Lunar Tropic
Aurora borealis,	73	126
Aurora australis,	126	75

NUMBER OF DAYS.

Aurora borealis,	81	119
Aurora australis,	125	81

For the investigation of the question of the periodicity of thunderstorms, the observations in Sweden during 1880–1895, 52,000 in number were used.



[1] The number of observations of auroras is considerably greater than the number of days with auroras, as on several of these days the phenomenon was observed more than once.

Digitized by Google

These observations were arranged according to the tropical month and synodic month periods. In the tropical period, the influence of the synodic was eliminated by the second method, in the synodic that of the tropical by the above given analogous method. There was thus obtained a well pronounced tropical, as well as synodic, month period for thunderstorms. In the tropical period, the maximum comes five days before the southern lunistice, and the minimum six days after. The extremes occur in comparison with those of the aurora about a fourth of a period too soon. The amplitude is 50% of the mean.

The synodic month period of thunderstorms has, as this investigation shows, a real existence. The true (corrected) variation exhibits a very pronounced maximum 3–4 days before the full moon, and a reduced minimum in the neighborhood of the first quarter. The apparent (uncorrected) variation exhibits a greater frequency of thunderstorms with a waxing than a waning moon. It seems as if the growing strength of the moon's light immediately before the full moon caused a pronounced maximum in the frequency of thunderstorms.

In the annexed drawing, we give the following curves borrowed from the work under review: *a.* For auroras: I. True tropical month period of auroras, second method, number of observations, Sweden, 1722–1896. *b.* For thunderstorms: Monthly periods of thunderstorms in Sweden, 1880–1895; II. Apparent tropical month period; III. True tropical month period; IV. Apparent synodic month period; and V. True synodic month period.

CHEVALLIER'S EXPERIMENTS ON THE INFLUENCE OF ELECTRIC RAILWAY CURRENTS ON GALVANOMETRIC MEASUREMENTS.[1]

The well-known experiments at the Physical Technical Reichsanstalt, at Charlottenburg, have shown that even at a distance of four kilometers from an electric road, all apparatus containing delicate magnetic systems is seriously affected. At the Potsdam Magnetic Observatory, the recording apparatus is influenced by an electric railway more than ten kilometers distant, and at Spandau, Germany, induction currents produced by a line one kilometer distant were detected by a sensitive DuBois Rubens Galvanometer.

These "long-distance" effects have recently been supplemented by some experiments by M. H. Chevallier, at the "Faculté des Sciences," Bordeaux, called forth by the introduction of the electric railway in that city, and its attending magnetic disturbances.

A Thomson reflecting astatic galvanometer which had previously shown great steadiness, was rendered useless the day the new electric system was put into operation, and, through the courtesy of its President, systematic experiments were made to determine the magnitude of the effects at various distances from the feeders, etc. One of the feeders passes under the sidewalk close to the building, and, ordinarily, carries currents varying continuously from 100 to 200 amperes.

At a distance of 5 meters the galvanometer (sensibility 100 megohms) experienced deflections of 30 to 40 mm. At 30 meters these were reduced to about one-eighth, but even at a distance of 80 meters they measured about

[1] Ciel et Terre, No. 1, March 1, 1901, p. 24.

Digitized by Google

1 mm. At the distance of 30 meters, the whole current available, 600 amperes, produced a deflection of 10–12 mm. At 35 meters from the middle of a double-track trolley line, the deflection was 3 to 4 mm, and at 60 meters, about 1 mm.

The above effects were found to be due to a direct influence on the magnetic system and not to induced currents, as they were not changed by opening or closing the galvanometer circuit. By encasing the galvanometer, as in the Hartmann & Braun and Siemens & Halske galvanometers, in a cylinder of sheet iron, 2.5 mm thick, the disturbances were completely suppressed.

It is evident that the above experiments can only give us a rough idea of the magnitude of the disturbances due to electric railways, as this depends upon the degree of astaticism of the system, the magnitude of the control field, the character of the suspension, etc. Without the missing data, the results, though interesting, are necessarily without application.

U. S. National Bureau of Standards. F. A. WOLFF.

F. H. BROWN ON LOCATING METAL ORES.

A patent issued December 31st, to Fred H. Brown, describes an application of the Wheatstone bri'ge principle in the location of metallic ores, minerals, etc. The source of current for the bridge arrangement is an induction coil, and a telephone is used in obtaining a balance. Two terminals from ends of one arm of the bridge are inserted in the earth at various distances apart, the earth thus becoming the unknown resistance in this arm of the bridge; the value of this resistance is then measured in the usual way.—*Electrical World and Engineer*, p. 130, January 18, 1902.

RESULTS OF MAGNETIC OBSERVATIONS AT MAGNETIC OBSERVATORY, KAZAN, RUSSIA, 1894–1897.[1]

The absolute observations have been made by M. C. Cegel; variation readings were taken three times a day by M. C. Cegel and E. A. Kartekovsky. The computations were made by E. A. Kartekovsky in a manner similar to previous years. The scale values for 1894, 1895, and part of 1896 have been taken the same as for 1892.

In 1896 the old variation instrument was removed from the east room to the west room of the variation observatory, and a new set of photographic variation instruments, Wild-Edelmann design, installed in the east room, and for that reason part of the readings in 1896 have been missed. In October, 1896, the scale values were redetermined by M. C. Cegel, which values have been adopted in the variation observations for the remainder of 1896 and for the entire year of 1897.

From July 15, at 9 P. M., to July 24, 1897, he found considerable disturbances in the values of the elements, because on the north side of the pavilion about 4,000 pounds of iron had been placed for the construction of a building. From August until October the construction of this building was continued. Its chimney is of iron and evidently has some influence on the values of the magnetic elements.

[1] ULJANIN, W. Observations faites à l'observatoire magnétique de l'Université Imperialé de Kazan publiées par —— ——, Directeur. Années 1894, 1895, 1896 et 1897. Kasan, 1899.

Digitized by Google

The absolute observations of the dip have been made entirely with the Adie Inclinometer, using but one needle, Needle Dover No. 6. No vertical force observations with the Lloyd balance are at present published. All dates are according to new style.

The Observatory is in latitude 55° 47′ North, and in longitude 49° 08′ East of Greenwich. The results for D and H are given for each day throughout the year at 7 A. M. and 1 and 9 P. M., the daily mean being the mean of these three hours. The mouthly daily means derived in this manner are given below.

The diurnal range of declination figures are the differences of D (7^h—1^h).

MONTH	Declination 7° E. +				Diurnal Range of Declination				Horizontal Intensity 18500 γ +			
	1894	1895	1896	1897	1894	1895	1896	1897	1894	1895	1896	1897
	′	′	′	′	′	′	′	′	γ	γ	γ	γ
January	37.8	43.9	44.0	50.5	1.0	1.2	0.7	1.9	76	67	118	135
February	39.2	44.9	43.6	50.9	2.1	1.7	2.1	2.2	62	53	114	104
March	38.5	46.0	43.2	51.3	6.0	5.9	6.1	6.1	66	68	111	107
April	38.8	45.9	39.1	52.2	9.3	9.3	8.1	8.5	65	53	117	106
May	37.9	44.4	47.2	59.0	12.7	12.1	11.8	11.4	80	65	78	104
June	38.6	44.4	54.4	60.3	10.1	13.2	10 0	9.8	78	72	107	100
July	39.9	38.4	46.9	58.1	10.3	10.4	10.4	8.2	68	102	105	113
August	40.3	44 7	50.6	60.5	9.0	9.6	9.3	10.6	63	103	96	63
September	40.1	40.2	43.8	54.0	7.0	7.1	9.1	8.1	64	100	89	101
October	40.6	43.6	50.3	52.1	4.4	3.8	3.9	4.9	77	98	92	109
November	42.6	44.7	52.0	53.7	1.2	1.0	2.2	1.5	76	88	130	164
December	42.2	44.4	49.7	55.0	1.2	2.2	0.9	—0.1	86	93	105	180
Mean	39.7	43.8	47.1	54.8	6.2	6.4	6.2	6.1	72	80	105	116

The results for inclination are as follows:

1894—	68° 37′.5	mean of	12	observations,	January–December.
1895—	35 .5	" "	5	"	February–December.
1896—	33 .7	" "	7	"	June–December.
1897—	34 .8	" "	6	"	January–July.

INFLUENCE OF CONVECTION CURRENTS UPON THE DEFLECTIONS OF DELICATE INSTRUMENTS.[1]

BY W. PRINZ.

M. PRINZ calls attention once more to the important effects of convection currents in the air upon the deflections of delicately suspended needles of all kinds. An extremely sensitive thermoscope is made by suspending a non-magnetic needle by a silk fiber in a glass jar. The needle may be of glass or straw, and should be unsymmetrical in form. If now a lighted cigar or the finger be brought near the jar the needle will swing toward it as though attracted by a magnet. The true explanation is, of course, that a convection current is set up and the needle is carried round until it reaches the point at which the air is moving vertically.

[1] De l'influence des courants de convection sur les indications d'instruments très mobiles. Extrait *Ciel et Terre*, 22e ann e, pp. 1–29, Bruxelles, 1901.

Digitized by Google

Attention was called to this action of air currents upon a delicate suspension as early as the eighteenth century, but it appears to have been persistently forgotten. The writer cites a long series of careful investigations in which such effects were noted, but in which the cause was ascribed to some "new force." Influenced by the persistence with which these effects are ignored or misinterpreted, M. Prinz has undertaken a series of elaborate investigations upon the movements of neutral needles, only examples of which need be mentioned.

A thermoscope was made, consisting of a copper bar weighing, with its lead counterweights, about 15 grams. This was placed diametrically in a celluloid sphere packed with cotton to prevent air currents inside. The whole, weighing about 42 gms., was suspended by a platinum wire 0.03 mm. in diameter in a copper cubical box which was placed oppposite the double window of a carefully-constructed constant-temperature room in the magnetic observatory at Uccle. The window was covered by a wooden shutter, and deflections of the suspended system could be caused only by convection currents within the copper box, caused by the difference of temperature between the shutters of the window and the interior of the room. Readings were taken each day at noon. The extreme variations on the diagram given amount to over five degrees, the deflections being invariably toward the window on sunny days, and away from the window on cloudy days. The passage of a cloud over the Sun was distinctly indicated by the deflection.

An old-style galvanometer with an astatic system weighing 325 grams was placed in the same room and observed daily for fifty days. The magnets moved through 1½ degrees, and the curve representing their motion followed accurately the course representing the slight changes of temperature in the room. Unfortunately the scale of the latter is not given.

In another case four thermoscope bottles were placed in a vault of the Observatory. The only opening to the vault was by a door opening upon a corridor seldom used. Daily readings were taken from March 17 to August 1. The daily variations were sometimes several degrees, but about May 10 the variations became violent, and finally the needle swung completely round from the quadrant away from the door to the quadrant nearest the door. During the winter the door was slightly cooler and during the summer slighly warmer than the walls of the room.

The entire investigation emphasizes most strongly the necessity of using every precaution to prevent air currents within magnetic and other instruments containing a delicate suspension, and M. Prinz makes the valuable suggestion that, whenever possible, the readings of such an instrument be compared with those of a similar instrument containing a neutral needle, and similarly placed.

NORMAN E. GILBERT.

HOBART COLLEGE, GENEVA, N. Y.

TOEPLER'S EXPLANATION OF BALL LIGHTNING.

Herr Toepler suggests an explanation of the mysterious ball lightning, founded on some interesting experiments he has made on the discharge from a large multiple plate influence machine, says the London *Electrical Review*. When one of the electrodes of the machine is a metal point, and the other is

Digitized by Google

a disk of some semi-conducting material, such as slate or basalt, an almost continuous discharge takes place, which appears at first as a glow, then, with increasing strength of current, becomes a tuft discharge and a tuft arc light. If a metal ball, which may or may not be insulated, is held between the poles, the same phenomena show themselves in it as if it were an electrode; *i. e.*, tufts, etc., are formed on it. An aperture in a non-conductor, such as a plate of mica, behaves much the same as the metal ball, a mass of light being formed in the aperture when the plate is held between the electrodes of the machine. With sufficiently strong current a row of luminous masses, separated by non-luminous spaces, forms in the path of the current on each side of the plate of mica, just as if the current alternately expanded and contracted in section. Toepler considers that these luminous masses may be produced by atmospheric discharges, and give rise to the appearance of ball lightning. Toepler's experiments are described in the Annalen d. Phys., vol. vi, p. 339.—*Electrical Review*, January 4, 1902.

EFFECT OF VERTICAL MOVEMENTS OF AIR ON ATMOSPHERIC ELECTRICITY.

F. LINKE dwells upon the fact that if at any place an electrostatic potential A exists, and a conducting body of capacity C is in equilibrium, a quantity of electricity $E_a = C\,A$ results. If we now bring this body to a place of potential B, then we should have a quantity of electricty $E_b = C\,B$ neglecting disturbing influence of the field; the difference $E = C\,(A-B)$ must become free, if no change takes place in capacity. In an electrostatic field, like that of the earth, any change of a body in the direction of the force lines must result in free electricity. The author finds in the rise and fall of charged clouds a cause of lightning potential, which to his mind is far more plausible than theories of the friction of water on ice and condensation of irons.—*Ann. der Physik*, No. 1, 1902, pp. 231–335.—Abstract by J. T. in *Am. Journal Science*, February, 1902.

MAGNETIC MEASUREMENTS IN A BALLOON.[1]

The most serious deficiency in our present knowledge of the Earth's magnetism is the lack of data regarding the variation with vertical distance above or below the Earth's crust. Without observations of this sort spherical harmonics show that we can not determine the actual distribution of the Earth's magnetism. Of utmost importance would be measurements of the variation in *vertical* intensity with the altitude; still, a long step has been taken when the corresponding changes in horizontal intensity can be reliably observed. An instrument that bids fair to satisfy this requirement is here described by Professor Ebert.[2]

Gay Lussac and Biot, in their historic ascension in 1804, failed to find any variation with increasing altitude. The improvements in instruments since that time, and especially the need of testing Gauss's theory of magnetic masses

[1] DR. H. EBERT, Magnetische Messungen im Ballon. Illustrirte Aeronautische Mittheilungen, October 1901, p. 137.

[2] Professor Ebert is also experimenting with a suitable vertical force variometer. —ED.

Digitized by Google

distributed in the interior of the Earth, make it important to repeat the observations with all possible accuracy. If Gauss's theory is correct, the horizontal intensity should decrease (near Munich) 0.0001 c. g. s. for each kilometer in altitude; while if a part of the magnetic field is due to the atmosphere, a different rate of decrease would be expected. Observations made in mountainous regions are cited, tending in fact to show a greater decrease than that demanded by the theory. Adolf Schmidt calculated that $\frac{1}{10}$ of the Earth's field was due to causes outside of the Earth's crust, presumably residing in the atmosphere, and also deduced the existence of vertical earth-air electric currents. Bauer integrated the magnetic intensity in zones around the Earth, and found a well-defined system of vertical earth-air electric currents related in some manner with the general atmospheric circulation. Elster and Geitel's discovery of free ions in the atmosphere also points to the existence of currents that would of necessity exert a magnetic effect.

The instrumental difficulties lie chiefly in the fact that magnetic instruments require above all things a stable and stationary mounting. The swaying of the balloon forbids the use of a fiber suspension. Its continual turning requires the instrument to be independent of any particular orientation to the magnetic meridian. If it drifts with the wind, local variations in the region passed over must be considered. Thus a magnetic survey of the region is necessary, as well as a knowledge of the diurnal variation during the observations; the latter, of course, to be derived from self-recording variometers at a not too distant point.

In 1899, Vogel and Emden attempted to observe oscillations in a balloon. The failure of the experiment, owing to the impossibility of stopping the sidewise swinging of the magnet, led to the adoption of the Heydweiller "double needle" variometer. This instrument consists of two magnets, mounted one above the other on pivot suspensions; by suitable adjustments, their axes can be made perpendicular to each other through the mutual repulsion of like poles. When this is attained, changes in the angle between the magnets are approximately proportional to changes in the Earth's horizontal component. As modified for aeronautical use by Dr. Ebert, the instrument gave results accurate to within 0.00044 c. g. s. units. In practice, the bobbing of the needles was found very troublesome, especially as the observer was obliged to move from one side of the instrument to the other, thus disturbing the equilibrium of the car. Copper dampers were tried, but found useless. These and other instrumental difficulties led the author to undertake the construction of a new form of Heydweiller variometer designed especially for use in a balloon. In this instrument each magnet system consisted of two parallel needles, 8.3 cm. long, one system being mounted about 15 cm. above the other inside a vertical brass cylinder, which was attached to the outer edge of the balloon car. Each pair of needles was rigidly fastened to an agate cone, which rested on a steel pivot. The lower system also carried a horizontal aluminum disk, graduated to degrees on its upper edge. From the upper system four long arms extended downward, ending in pointers close above the graduations on the disk, and 90° apart. By looking down from above, through holes in a disk carried by the upper system, angles could be read in any position without error from parallax, and without moving the body. The upper pivot could be raised and lowered, so that for any

Digitized by Google

value of H the needles could be brought into positions at right angles to each other. By means of a small bar-magnet the directions of the needle systems could be interchanged, for the elimination of instrumental errors. The attempt was made to damp the disturbing oscillations by filling the containing cylinder with alcohol, but without success, owing to rotations set up in the liquid itself.

The variometer was calibrated by placing it in a weak artificial magnetic field of known intensity. Angles could be read to within tenths of a degree, and results were accurate within 0.00010 c. g. s. units. The instrument has been tested in two ascensions, but the results are not given. Still another improved form is under construction, in which vanes will be provided to damp the swinging of the needles. The results will be awaited with much interest.

W. G. CADY.

CHANGE IN THE MAGNETIC HORIZONTAL INTENSITY WITH ALTITUDE.[1]

BY A. POCHETTINO.

The author made observations of the relative horizontal intensity in August and September, 1899, at stations differing in altitude up to 2,100 meters, in a region free of local disturbances. Applying corrections due to the differences in geographical position of the stations, as deduced from the numerous observations made in the vicinity by Messrs. Keller and Folgheraiter, he found on the average, a *decrease* in the horizontal intensity of 0.0005 c. g. s. per 1,000 meters—5 times that resulting from theory. This value exceeds that of Sella's at Monte Rosa, which region, however, is not entirely destitute of local disturbances; and also that of Liznar, in Austria, for a difference of altitude of 400 meters.

MAGNETIC ANOMALY NEAR IRON MINES OF KRIVOI-ROG, RUSSIA.[1]

In the summer of 1898, Mr. Passalsky, magnetic observer at the magnetic and meteorological observatory of the University of Odessa, made a magnetic survey of the country in the vicinity of the iron mines of Krivoi-Rog, in the Dneiper Basin, about 150 miles northeast of Odessa, and found very great anomalies. The results of this survey as well as a review of what is known of the earth's magnetism, were presented in his memoirs "Sur l'étude de la distribution du magnétisme à la surface du globe terrestre," published in the Bulletin of the Imperial University of Odessa, Vol. LXXXV, pp. 1—547, 17 maps and 17 illustrations. Among the subjects discussed in this memoir were the effect of height upon the magnetic elements, the causes of magnetic anomalies, the form and properties of the iso-magnetic lines, X = constant, Y = constant, Z = constant. This memoir was edited by Mr. Boris Weinberg, after the death of Mr. Passalsky. He has judged the 17 maps worthy of sep-

[1] Se e come la forza magnetica terrestre varii coll'altezza sul livello del mare. Nota. Rendiconti della R. Accad. dei Lincei. Estr. vol. viii, pp. 204–212, Roma 1899.

[1] PASSALSKY, P. T. Anomalies magnétiques dans la région des mines de Krivoi-Rog, Odessa, 1901.

Digitized by Google

arate publication, as they present the principal results of the survey of the Krivoi-Rog region.

Determinations of the three magnetic elements were made at over 400 places in the area between latitude 47° 48′ and 48° 28′, and longitude 2° 53′ and 3° 27′ east of Pulkowa. In this limited area, Passalsky found declination ranging from +65° to —90°, inclination from 45° to 85°, and horizontal intensity from 0.055 to 0.700 c. g. s. units. Maps I to IX show the distribution of stations, declination, horizontal intensity, inclination, northerly, easterly, and vertical components, total intensity and force anomalies respectively for the whole region. Especially detailed surveys were made of two small areas where the anomalies were greatest, the stations often being only 21.6 meters apart. The results for these two areas are presented separately on maps X to XVII. Mention was made in this Journal (for December, 1899) of the disturbed area at Kursk, where anomalies almost as great as those at Krivoi-Rog occur without any apparent cause. The latter are presumably due to the presence of magnetic iron ore. It is a great misfortune that so enthusiastic a worker in the field of terrestrial magnetism as Mr. Passalsky should have died at the early age of thirty years. D. L. HAZARD.

MAGNETIC OBSERVATIONS IN ROUMANIA IN 1898 AND 1899.[1]

In the summer of 1898, a series of magnetic observations was begun in Roumania for the purpose of constructing magnetic charts of that country. The plan adopted called for the occupation of 140 stations throughout the country, making about one station for each 940 square kilometers.

In 1898 ten stations were occupied. At one of them, however, the day was one of much magnetic disturbance, and observations were repeated there the following year. In 1899, thirty-three additional stations were occupied. The three elements were observed at each station.

The work was carried on by S. C. Hepites, Director of the Meteorological Institution of Roumania, assisted by I. Murat, Chief of the Magnetic Service, and the following instruments were used: Theodolite-Magnetometer Chasselon, No. 9; Dip Circle Chasselon, No. 14; Chronometer Molyneux, No. 1193; Metronome Giteau, and Aneroid Barometer Tonnelot.

The astronomical meridian was determined by observing the altitude and azimuth of the Sun when near the prime vertical. For each determination at least ten pointings were made on the Sun, the telescope being reversed after each pointing.

The declination and horizontal intensity were determined with two magnets used successively, and the mean of the two results was adopted.

The dip was observed in the plane of the magnetic meridian, using two needles and reversing polarity.

At Pitesci, the dip observations would seem to be defective; thus needle No. 1 gives 60° 0′.5, and needle No. 2, 59° 12′.1. The author takes the mean of the two results.

[1] HEPITES, ST. C. Contributiuni Fisica Globului. IV. Determinări magnetic in România. Anul, 1898. Bucharest, 1899. V. Determinări magnetic in România. Anul, 1899. Bucharest, 1900.

Digitized by Google

The results obtained are given in the following tables:

No.	Station	Date	Latitude	Longit'de E. of Gr.	West Declination	Inclination	Horiz'nt'l Intensity
			° ′	° ′	° ′	° ′	γ
1	Bucharest,	July 5, '98.	44 25	26 06	4 31.8	58 51.1	23302
2	Craiova,	" 7, "	44 19	23 48	5 19.6	58 54.9	23186
3	Pitesci,	" 9, "	44 51	24 53	5 00.7	59 36.3[1]	23083
4	Calarasi,	" 13, "	44 12	27 21	3 46.0	58 54.9	23433
5	Jasi,	Aug. 2, "	47 10	27 29	3 38.2	60 53.8	22201
6	Roman,	" 3, "	46 55	26 56	3 38.8	60 43.8	22214
7	Constanta,	" 6, "	44 11	28 39	3 25.6	59 03.7	23439
8	Calafat,	" 30, "	43 59	22 57	5 41.4	58 57.6	23169
9	Braila,	Sep. 9, "	45 16	27 58	3 05.8	58 45.5	23336
10	Galati,	July 26, '99.	45 26	28 02	3 00.2	59 26.9	22981
11	Comana,	" 18, "	44 09	26 07	4 26.2	58 17.8	23369
12	Giurgiu,	" 19, "	43 53	25 58	4 44.3	58 12.6	23537
13	Lehliu,	" 20, "	44 29	26 46	3 51.2	58 46.4	23338
14	Teis,	" 21, "	44 56	25 26	4 34.1	59 22.7	22999
15	Titu,	" 22, "	44 40	25 33	4 46.7	59 04.5	23201
16	Vames,	" 27, "	45 30	27 51	2 57.9	59 40.4	22937
17	Tecuciu,	" 28, "	45 49	27 26	3 25.4	59 55.9	22735
18	Husi,	" 29, "	46 42	28 03	2 43.3	60 31.7	22341
19	Berlad,	Aug. 2, "	46 15	27 41	3 11.9	60 17.5	22472
20	Vaslui,	" 3, "	46 39	27 44	3 07.7	60 45.3	22329
21	Rediu,	" 4, "	47 34	27 14	3 52.7	61 32.8	21901
22	Dorohoiu,	" 5, "	47 59	26 25	3 33.8	62 07.6	21661
23	Adjud,	" 8, "	46 06	27 10	3 24.4	59 59.2	22540
24	Palanca,	" 9, "	46 31	26 04	4 09.9	60 41.0	22304
25	Tg.-Ocna,	" 10, "	46 17	26 37	3 38.4	60 18.7	22422
26	Bacau,	" " "	46 33	26 56	3 33.7	60 46.6	22333
27	Piatra,	" 11, "	46 56	26 22	3 48.4	61 04.2	22181
28	Fetesci,	" 15, "	44 23	27 50	3 47.2	58 34.7	23325
29	Mangalia,	" 16, "	43 37	28 37	3 10.0	58 07.1	23737
30	Portita,	" 17, "	44 43	29 03	3 03.1	58 54.5	23365
31	Insula Serpilor,	" 18, "	45 15	30 12	2 08.5	59 13.7	23382
32	Sulina,	" " "	45 09	29 40	2 23.5	59 20.5	23275
33	Mahmudia,	" 19, "	45 04	29 06	3 00.3	59 16.7	23188
34	Sf. Gheorghe,	" 20, "	44 54	29 36	2 32.4	59 12.3	23292
35	Chilia-Veche,	" 21, "	45 25	29 18	2 03.0	59 31.8	23005
36	Tulcea,	" " "	45 11	28 49	3 10.1	59 17.6	23129
37	Isaccea,	" 22, "	45 16	28 29	2 59.9	59 21.2	23115
38	Ploesci,	" 26, "	44 56	26 02	4 27.0	59 12.6	23081
39	Buzeu,	" 28, "	45 09	26 50	4 00.5	59 21.5	22948
40	Ramnicul-Sarat,	" 29, "	45 23	27 03	3 55.8	59 32.3	22803
41	Eocsani,	" 31, "	45 41	27 12	3 39.7	59 50.0	22790
42	Predeal,	Sep. 2, "	45 30	25 35	4 29.7	59 49.6	22701
43	Babadag,	" 4, "	44 53	28 40	3 01.4	59 11.1	23247

In the year 1858, magnetic observations were made in southeastern Europe by Karl Kreil, Director of the Meteorological and Magnetic Institution of Austria. Five of his stations were located in Roumania, and were reoccupied

[1] Defective. See remark in above text.

Digitized by Google

in 1898 and 1899. By comparing the results the mean secular change per year between 1858–1898 (1899) is found to be as follows:

Station	Declination			Inclination			Horizontal Intensity		
	1858	1898 / 1899	Mean Secular Change per Y'r	1858	1898 / 1899	Mean Secular Change per Y'r	1858	1898 / 1899	Mean Secular Change per Y'r
	° ′	° ′	′	° ′	° ′	′	γ	γ	γ
Calafat, . . .	9 09.3	5 41.4	5.2	59 59.9	58 57.6	1.6	22568	23169	15
Bucharest, . .	7 55.4	4 31.8	5.1	59 51.5	58 51.1	1.5	22638	22302	17
Galati, ...	6 34.1	3 00.2	5.2	61 08.5	59 26.9	2.5	22169	22981	20
Sulina, ...	6 13.3	2 23.5	5.6	.....	.....	.....	22647	23275	15
Insula Serpilor,	5 48.7	2 08.5	5.4	60 18.0	59 13.7	1.6	22757	23382	15

WM. F. WALLIS.

OBSERVATIONS OF AURORA AUSTRALIS OF THE BELGIAN ANTARCTIC EXPEDITION.[1]

In the scientific reports of the Belgian Antarctic Expedition, Mr. Henryk Arctowski makes his report of the observations of the Aurora Australis made in 1898 while the Belgica was fast in the ice.

He describes in detail the individual auroras observed, by means of the notes and sketches made at the time of observation. He also gives a brief account of the meteorological conditions prevailing at the time. He concludes by discussing the diurnal and annual variations in the frequency of occurrence of auroras as indicated by his observations, and by pointing out certain analogies between northern and southern auroras. These conclusions had previously appeared in Ciel et Terre and have been noticed in this Journal (Vol. V., p. 85).

D. L. HAZARD.

THE MAGNET IN SURGERY.

Dr. Garel, of Lyons, has drawn a French nail about two inches long from the bronchial tube of a boy of eighteen months from Buenos Ayres. The nail had been there for some time, causing the child to cough much. Röntgen rays showed the position of it, and an electro-magnet drew it out. Another successful operation of the same kind has been performed by Dr. Piéchaud, of Bordeaux, on a child of three years. In this case the trachea was opened to get a projection from the pole of the magnet near the nail. These experiments are well worth the attention of surgeons everywhere.—*From the London Globe.*

[1] Resultats du Voyage du S. Y. Belgica en 1897, 1898, 1899. Rapports scientifiques. Meteorologie. Aurores Australes par HENRYK ARCTOWSKI. Anvers, 1901. 4to. 64 pages and 2 plates.

Cf. The Antarctic Voyage of the "Belgica" during the years 1897, 1898, and 1899, Geogr. J., Oct., 1901.

Digitized by Google

RECENT PUBLICATIONS

ADMIRALTY. Manual for the deviations of the compass. Originally edited in 1862, by E. J. Evans and Archibald Smith. 7th Ed. London, 1901 8° IX, 211 pp. 9 pl. Price, cloth, 3 sh.

AKADEMIE DER WISSENSCHAFTEN ZU ST. PETERSBURG. Systematisch und alphabetisch geordenete Liste der von der Kais. —— und dem Physikalischen Central Observatorium in der Zeit von 1894–1900 veröffentlichten meteorologischen und magnetischen Arbeiten.

BALDI BERNARDINO. L'invenzione del bosolo da navigara. Poema inedito pubblicato per cura di GIOVANNI CANEVAZZI, Livorno, R. Giusti 1901. 8° .XXVII, 74 pp. Price Lire 2.50.

BASCHIN, OTTO. Die Deutsche Südpolar Expedition. Mit drei Tafeln. Repr. Zeitschrift der Gesellschaft für Erdkunde zu Berlin, Bd. XXXVI, 1901, No. 4. Pp. 56, Berlin, 1901. [An excellent résumé of the preparations and purposes of the German Expedition. The three plates present a portrait of Prof. Drygalski, a picture of the ship and a picture of the crew on deck. *Cf* pp. 1-8.]

BERTELLI, TIMOTEO. Sopra un nuovo documento risguardante l'invenzione della bussola nautica. 8° 8 Pp. Repr. Rivista d. Fisica, Pavia, 1901.

CENTRALANSTALT FÜR METEOROLOGIE & ERDMAGNETISMUS. Jubelband zur Feier des 50jährigen Bestandes der k. k. Centralanstalt. Denkschriften der Kais. Akad. d. Wiss. Math.-naturw. Classe, 73. Bd. Vienna, C. Gerold's Sohn 1901, 4°. [Contains an historical review of the work of the Institution during its half century of existence, and various meteorological papers.]

—— ——. Zur Einführung in die neueren Anschauungen über die Ursachen der Luftelectricität. Met. Z. S. Jan. 1901, pp. 17-24. [A résumé of the fundamental principles and experiments upon which the most recent theories of atm. elect. are based.]

EBERT, HERMAN. Messungen der electrischen Zerstreuung im Freiballon. Repr. Sitzber. d. math.-phys. Cl. d. bayer. Acad. d. Wiss. XXX, 1900. Pp. 511–532, München, 1901.

—— ——. Ueber die Bedeutung luftelectrischer Messungen im Freiballon Repr. Illustr. Aeronaut. Mittheil. 1901, Heft I. Pp. 11–24.

—— ——. Weitere Messungen der electrischen Zerstreuung in grossen Höhen. Repr. Sitzber. bayer. Acad. Wiss. XXXI, 1901. Pp. 35–51.

ELSTER, J. und GEITEL, H. Weitere Versuche über die Electricitäts-Zerstreuung in abgeschlossenen Luftmengen. 4°. 4 pp. Repr. Phys. Z. S. II. Pp. 560–563, 1901.

HEPITES, STEFAN C. Manifestatiune cu ocasiunea jumătăteĭ de veaca a vîrsteĭ sale 5–17 Februarie 1851—5–18 Februarie 1901. Buscaresei, 1901. 60 pp. with portrait of S. C. Hespites. 4°. [Relating to celebration of 50th birthday with letters of congratulations, biographical sketch and list of papers. *cf* p. —.

MUXO ALEJANDRO. Auroras Polares. Rêvista de Ciencias, Habana. Año 1.

PAULSEN, ADAM. 1. Études spectrographiques de l'aurore boréale. Communication préliminaire. 8°. 4pp. Repr. Oversigt Kgl. Danske Vidensk. Selsk. Forh. 1900, No. 2.
2. Suite des recherches sur l'analyse spectrale de l'aurore boréale. 8°. Repr. Oversigt Kgl. Danske Vidensk. Selsk. Forh. 1900, No. 3. Pp. 243–248.

Digitized by Google

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VII JUNE 1902 NUMBER 2

A THEOREM ON FOURIER SERIES, AND ITS APPLICATION IN GEOPHYSICS.[1]

By A. NIPPOLDT, JR.
Translated by S. J. Barrett.

If we put the interval 2π, in which a Fourier series assumes every possible value, equal to the natural period[2] of a geophysical element, we obtain the most natural and appropriate of all the common representations of the periodic process, since in this case the representing function and the function represented have the same periodicity. In addition to this, the individual waves attain a real significance in certain circumstances; for example, when the periodic process is to be attributed to stationary vibrations, as in the case of the diurnal variation of the atmospheric pressure. But even in the case in which the waves of higher order are to all appearances merely computation quantities, the physical analysis of the process represented, according to its causes, can still be effected by the series, though of course only with the assistance of modes of procedure lying quite outside the method (of Fourier); namely, by the comparison of the coefficients for different times and places in which the different causes act in opposite senses.

It was with such aid that the author succeeded in showing that that field to which, according to Schuster-Bezold,[3] the diurnal variations of the Earth's magnetism are to be attributed, is composed of two parts, one corresponding to the "solar" part of the weather, the other to the "terrestrial" part. Both parts have the period

[1] From the *Physikalische Zeitschrift*, 2ter Jahrg. No. 24, pp. 363-365.

[2] Strictly speaking equal to that derived with the aid of Schuster's "Periodogram." *Cf.* T. M., Vol. III, p. 13, et VI, p. 42.

[3] See next number of T. M.—ED.

Digitized by Google

24 hours, so that in the Fourier representation the solar part is given by the first term, and the terrestrial part by the sum of all the rest. The solar part is thus represented by a stationary vibration, and the terrestrial part, in a purely mathematical way, by the terms of the second order; while the individual waves have, beyond this, no independent existence.

If the series representation is applied with the necessary caution, and only when its employment is justified,[4] it is thus capable of furnishing valuable aid in the thorough investigation of the causes of the periodic phenomena of geophysics. We shall therefore in what follows enunciate a theorem which, though quite simple, is likely to have a wide range of application, at least in geophysics.

Let $f(t)$ be a function which admits of the development

$$f(t) = a_0 + \sum p_n \cos nt + \sum q_n \sin nt.$$

Let $f(t)$ be, in addition, a linear function of the independent variables $x_1, x_2, x_3, \ldots, x_m$, where the quantities x_m, on their part, admit of the development

$$x_m = \Phi_m(t) = (a_0)_m + \sum (p_n)_m \cos nt + \sum (q_n)_m \sin nt.$$

What functions of the quantities $(p_n)_m$, $(q_n)_m$ are then the coefficients p_n, q_n?

Since the variables $\Phi_m(t)$ are independent of one another, $f(t)$, a linear function of these variables, is given by the equation

$$f(t) = c_1 x_1 + c_2 x_2 + \ldots + c_m x_x = \sum_1^m c_m x_m.$$

Thus we have

$$a_0 + \sum p_n \cos nt + \sum q_n \sin nt = \sum_1^m c_m (a_0)_m + \sum_1^m \sum (p_n)_m \cos nt + \sum_1^m \sum (q_n)_m \sin nt.$$

Thus

$$a_0 = \sum_1^m c_m (a_0)_m; \quad p_n = \sum_1^m c_m (p_n)_m; \quad q_n = \sum_1^m c_m (q_n)_m.$$

[4] *Cf.* A. NIPPOLDT: Zeitschr. f. math. u. naturw. Unterricht, XXIX, 401, 1898.

Digitized by Google

This result is so self-evident that the theorem, which for simplicity will be called the "coefficient theorem," has in fact already been deduced and applied for some special cases. But its general usefulness has not been known hitherto.

a_0 denotes, as is known, the mean value about which the oscillation takes place, while p_n and q_n determine the amplitude of the n th wave. c_m is a function of $x_1, x_2, \ldots, x_{m-1}$. The theorem thus states, in the first place, that *the amplitude of the n th resultant wave depends only upon the n th generating waves, and in the same manner in which the mean value of the resultant function depends on the mean values of the generating functions.*

The quantities x_m are what the author has previously defined as "primary elements," while $f(t)$ represents a "secondary element."[5] The theorem thus states that the variation of the secondary element (perhaps inaccessible to observation) can be computed from the variations of the primary elements, while *the variation of the secondary element depends upon the variations of the primary elements as the absolute values about which the oscillations take place depend upon one another.*

The possible applications of the theorem will now be mentioned.

In pure computation. If all the quantities x_m coming into consideration have been harmonically analyzed, the theorem makes it possible to dispense with the analysis of $f(t)$. For this purpose, at the instance of E. Schering, an application of the theorem has already been made by Messrs. Huff, Meldau, Garthe, and Kind, in order to ascertain from the coefficients of the horizontal intensity and declination of the Earth's magnetic field the corresponding magnitudes of the rectangular components. The variation equation for the north-south component is

$$\triangle X = \cos \delta \triangle H - H \sin \delta \sin 1' \triangle \delta.$$

By the coefficient theorem we have then, simply,

$$(p_n)_X = \cos \delta \, (p_n)_H - (p_n)_\delta \, H \sin \delta \sin 1'$$

which shows very clearly how the coefficients depend on one another in the same manner as the absolute values; that is, in this case, as X depends on H and δ.

Especial importance attaches to this kind of application when the variations of the secondary element can not be observed. An example is given further below.

[5] Theoretische Grundlagen der Wetterprognose. Gaea XXXIV, 355, 1898.

Digitized by Google

In physical analysis. If the physical nature of the individual waves of the component functions has been established, the theorem extends it to the waves of like order of the resultant function. Thus the author has been able to show that the diurnal variation of the Earth's magnetic declination is composed of a solar and a terrestrial part. Since now

$$\triangle \delta = c/H \, (\cos \delta \triangle Y - \sin \delta \triangle X)$$

$\triangle X$, $\triangle Y$, and together with them, in general, the potential of the diurnal field (since it can be computed from $\triangle X$ and $\triangle Y$ alone), according to the coefficient theorem, likewise possess both these constituents, as already mentioned above.

Theoretical realization. The theorem gives, furthermore, the relation between the amplitude (of variation) and the absolute value. Thus, for example, if the way in which the latter depends on the geographic latitude and longitude, the elevation above or depression below the Earth's surface, etc., is known, then also, without the necessity of its measurement, the way in which the variation depends on these quantities is known. This is contained also in an empirical law of L. A. Bauer[6] on the inverse proportionality between the absolute value of the Earth's magnetic field and the amplitude of the variations. On the other hand, the absolute values can also be astertained from the known variations.

Practical realization. The phenomena of meteorology are more accessible to experiment. The meteorological nature of the Schuster-Bezold field of the diurnal variation of the Earth's magnetism can be explained only with the help of terrestrial electric processses, as, for example, by a diurnal variation of the electric conductivity of the air. Measurements of the variations of this element, even with the help of balloons, are to-day as good as infeasible. Nevertheless, one can find in the laboratory the law according to which the conductivity of the air depends on its state and composition. If then the air under investigation is brought into the states corresponding to the normal states of the air at different altitudes, the (law of the) decrease in conductivity with the altitude will be obtained, and with it, by the coefficient theorem, the diurnal variation of the conductivity with the altitude. Thus a quantitative examination can be made of the electric nature of the variations of the Earth's magnetism. The ascensions of the Berliner Verein für Luftschiffahrt have determined what normal

[6] T. M., Vol. II, p. 70.

Digitized by Google

air is at different altitudes, but the difficulty lies in the investigation of the conductivity of such dense air as corresponds to the lower atmosphere.

Elimination of the variations. It often happens that the (law of the) dependence of a geophysical element on a certain quantity is only approximately known, because the unknown variations could not be eliminated. An example is furnished by the decrease of the dampness and temperature of the air with the altitude. So far as the state of the free atmosphere is considered here, we are concerned only with observations made with kites and balloons; but these are not distributed regularly through the day and the year. If the function which these elements are of the altitude is approximately known, however, the variation correction can be computed for every altitude from the harmonic terms of the dampness and temperature of the air on the Earth. For the dampness, Suering[7] computed an empirical exponential formula; while Berson, to whom the measurement of the temperature of the air by means of balloons is due, has given up an analogous representation, because he came to the conclusion, otherwise so well justified, that such a formula gave only a mathematical representation.

General significance. The theorem leads to a general and consistent theory of the periodic phenomena on our Earth. If, for example, the temperature had a solar and a terrestrial part, very many of the secondary elements depending upon it would likewise have this constitution; namely, when the other effective primary elements were composed of corresponding parts.

The limits of validity. When a secondary element is a non-linear function of a primary element, i. e., a function of a degree higher than the first, as of the degree k, we must put $\Phi(t) = x_m^k$ in the series, when the coefficient theorem can again be applied. Further, the variables x_m must, according to our hypothesis, be independent of one another; and it is necessary, in the third place, that no external forces act directly upon $f(t)$; i. e., only so-called forced waves or only free waves can enter; all which must be investigated for the particular case considered.

Analogies from pure physics. Corresponding to the extended application in physics of trigonometric series, numerous analogies to the application of the coefficient theorem are found in physics. Only two cases, however, will be mentioned. One consists of the theorem of Poisson, according to which the n th spherical har-

[7] Wiss. Luftfahrten d. Vereins für Luftschiffahrt, III.

Digitized by Google

monic term of a potential corresponds to a proportional term in the induced potential. The other is the theorem developed by C. H. Wind,[8] which expresses the energy at a point P due to a source of disturbance at a point Q. His formula is

$$\omega_n a_n \sin\left[n\frac{\pi(t-t_\phi)}{T} + X_n\right] = c_m u_n \sin(U_n + nt).$$

There is only this difference, that ω_n, in the way in which it is here applied, becomes a function of the instrumental data, and also a function of n, since forced waves appear. Otherwise ω and Ω, deduced therefrom, for all waves would have to be equal in one component; i. e., to be the same function according to which an impulse would be propagated in the medium. There exists here, as has been said, only an analogy, which however, appeared to me interesting enough to mention. The real difference between this and the questions in geophysics mentioned here is that the disturbance at Q can have any form whatever, and need not be uniform, periodic, or harmonic at all in any interval of time.

Also in dealing with geophysical questions it will always be necessary to inquire whether the conditions of the problem in hand do not overreach the limits of the validity of the theorem, just as, in the application of Fourier series in general to this province of knowledge, it is necessary to proceed cautiously and critically. But then also the series will be found a very effective auxiliary.

THE MAGNETIC OBSERVATORY, POTSDAM.

[8] Physikalische Zeitschrift, II, 189–196, 1900.

Digitized by Google

NOTICE OF MAGNETIC DISTURBANCE DURING ERUPTION OF MONT PELÉE, MARTINIQUE..

By L. A. Bauer.

On May 8, 1902, at 11.59 A. M., Greenwich mean time, a magnetic disturbance occurred which began simultaneously at the two Coast and Geodetic Survey magnetic observatories in the United States, viz: at Cheltenham, Maryland, and Baldwin, Kansas. Taking the longitude of Mont Pelée, Martinique, as 4.04.6 W. of Greenwich or of St. Pierre 4.04.7, this magnetic disturbance began at 7.54 A. M., St. Pierre (or Mont Pelée) local mean time. The newspaper reports, in general, agree that the first eruption of Mont Pelée occurred at about 8 A. M. May 8th and it has been reported that the town clock of St. Pierre was found stopped at 7.50.

The reports received thus far from other observatories, viz: Honolulu (Hawaiian Islands), Toronto (Canada), Stoneyhurst (England), Val Joyeux (France), Potsdam (Germany), and Pola (Austria) show that this disturbance was quite general, and that it began practically simultaneously at all of them. The horizontal intensity was the element principally disturbed.

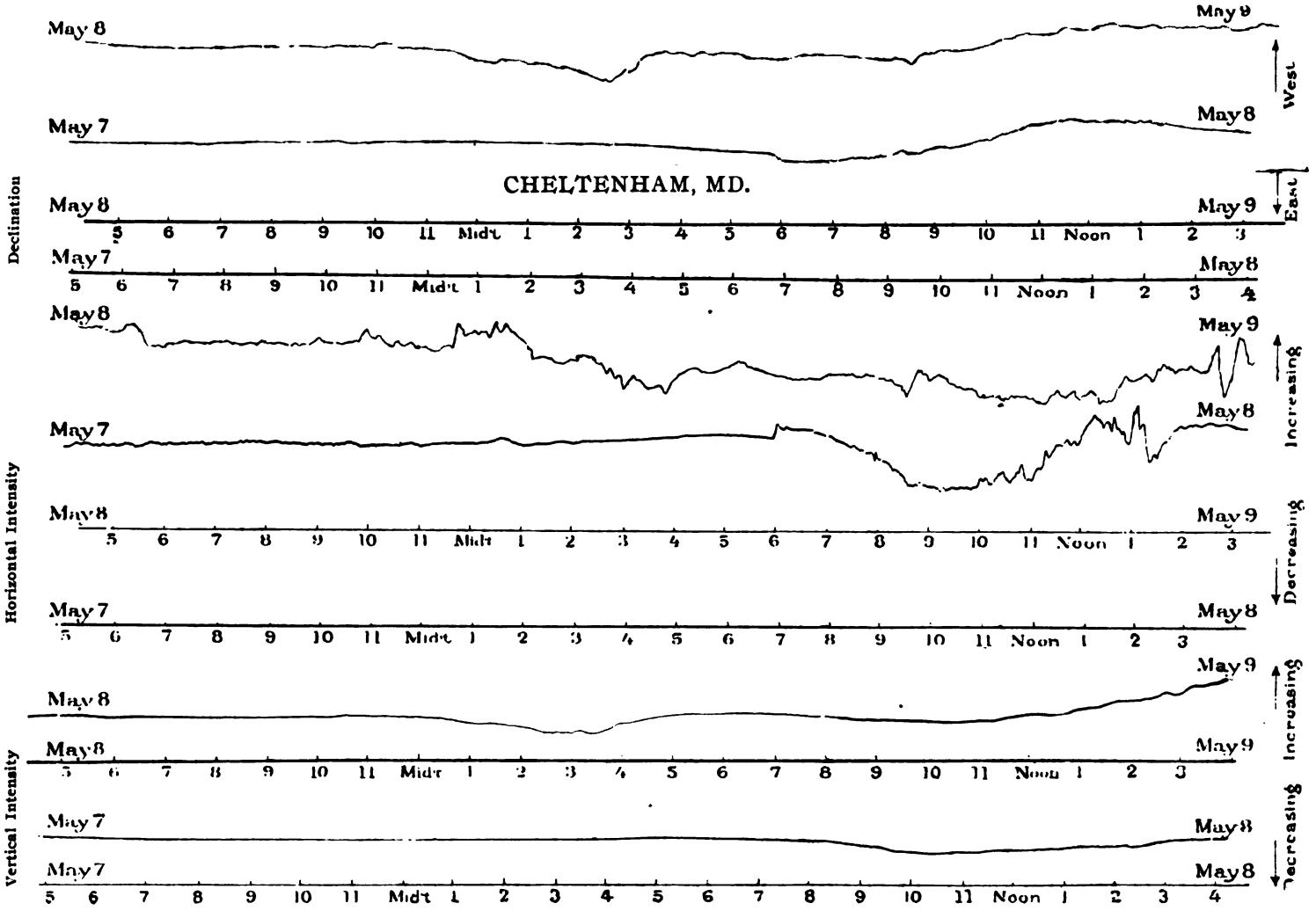
Several extremely interesting magnetic disturbances occurred between April 10th and May 8th, possessing striking similarities with each other and the one of May 8th, the similarities in magnitude and direction extending to the three elements, declination, horizontal, and external intensity. Throughout the period of the eruptions there were magnetic perturbations of greater or less degree, another striking coincidence occurring at the second eruption of May 20th, in which case, however, the perturbations were not as great as on May 8th.

A seismic effect on May 18 referable to the Guatemala earthquake has also been experienced by all observatories which have thus far reported.

Fuller information regarding these disturbances will be given in a future number. In response to a request sent by Mr. O. H. Tittmann, Superintendent of the Coast and Geodetic Survey, to the various observatories, reports and copies of the magnetograms are being received.

The diagram opposite is a reproduction (half-scale) of the magnetograms May 7th-8th obtained with the Adie magnetograph mounted at the Cheltenham Magnetic Observatory at which an Eschenhagen magnetograph has likewise been installed. The suddenness with which the disturbance of May 8th began is especially exhibited by the horizontal intensity curve.

Digitized by Google


CHELTENHAM, MD.
Declination
Horizontal Intensity
Vertical Intensity
May 8
May 9
May 7
May 8
West
East
May 8
May 9
5 6 7 8 9 10 11 Midt 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3
May 7
May 8
5 6 7 8 9 10 11 Midt 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4
May 8
May 9
May 7
May 8
Increasing
Decreasing
May 8
May 9
5 6 7 8 9 10 11 Midt 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3
May 7
May 8
5 6 7 8 9 10 11 Midt 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3
May 8
May 9
May 7
May 8
Increasing
Decreasing
May 7
May 8
5 6 7 8 9 10 11 Midt 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4

Digitized by Google

UEBER DEN EINFLUSS DER SPIEGEL-COLLIMATION BEI SPITZEN-AUFHAENGUNG AUF DECLINATIONS-MESSUNGEN.

VON K. HAUSSMANN IN AACHEN.

Die Annahme, dass der Collimations-Fehler eines freischwingenden Declinations-Magnets durch das Umlegen in Wegfall komme, gilt nur für *den* Fall, dass die *Verbindungs-Linie* der zwei Aufhänge-Puncte *durch den Schwerpunct* des Magnet-Systems geht. Für die Aufhängung an einem Faden ist dies leicht zu bewirken, nicht aber für die Bewegung auf einer Spitze.

1) Bei der Pinnen-Aufhängung ist die genannte Forderung (Schwerpunct in der Verbindungs-Linie der beiden Aufhänge-Puncte) erfüllt, wenn die Axen der Ausschleifungen des Doppel-Hütchens zusammenfallen mit der geometrischen Axe der Fassung des Hütchens, bez. der Axe der Hülse, in der das Doppel-Hütchen sich bewegt Allgemein trifft die Forderung noch zu, wenn die Axen der Ausschleifungen des Doppel-Hütchens parallel und symmetrisch zur Axe der Fassung liegen und der Schwerpunct in beiden Lagen gleich tief unter dem Aufhänge-Punct liegt. Zu diesen Voraussetzungen für die Construktion kommt noch die weitere für die Messung, dass der Magnet in seinen beiden Lagen genau centrisch auf die Pinne gesetzt wird, oder wenn dies aus mechanischen Gründen nicht möglich ist, dass die Pinne zwischen beiden Magnetlagen um 180° gedreht werde, bei genau gleicher räumlicher Lage des Magnets.

Aber diese Forderungen lassen sich bei den gegenwärtigen Einrichtungen nicht erreichen. Das Doppel-Hütchen so auszuschleifen, dass die Axen der beiden Ausschleifungen parallel sind oder zusammenfallen; das Hütchen so zu fassen, dass diese Axen symmetrisch werden zur Längs-Axe des Fassungscylinders oder damit zusammenfallen, das dürfte bei der Kleinheit des Hütchens nur durch Zufall zu erreichen sein. Das richtige Aufsetzen des Magnets auf die Pinne ist aber bei der neuen Ausführung des Magnet-Gehäuses — Umlegen ohne Abnehmen des Deckels — bis jetzt ebenfalls noch nicht möglich.

Deshalb wird bei den jetzigen Einrichtungen trotz des Umlegens des Magnets ein aus der Spiegel-Collimation entspringender Fehler in die Messung eingehen. Allerdings hat — richtiges Aufsetzen auf die Pinne vorausgesetzt — dieser Fehler einen konstanten Be-

Digitized by Google

trag, er lässt sich für jedes Instrument durch Vergleichs-Messungen an einem magnetischen Observatorium bestimmen und in Rechnung ziehen.

2) Das genau centrische oder wenigstens zur Axe der Hütchen-Fassung symmetrische Aufsetzen des Magnets auf die Pinne ist, wie schon bemerkt, ebenfalls nicht mit Sicherheit zu erreichen. Der Magnet sezt sich nicht von selbst genau in dem Scheitel des parabolischen Ausschliffs auf die Pinne auf. Es wird vielmehr um den Scheitel herum eine Kuppe geben, innerhalb deren die Pinne in jedem beliebigen Puncte angreifen kann. Der Rand dieses Abschnitts wird von den Puncten gebildet, in denen die Projection der Schwerkraft auf die Meridian-Tangente des Ausschliffs gerade entgegengesetzt gleich ist dem Widerstande durch die Reibung. Ausser vom Gewichte des Magnets ist also die Grösse dieses Abschnitts abhängig von der Pinnen-Spitze, auch vom Zustande des Hütchens selbst. Durch die Schwingungen des Magnets, besonders aber durch leichtes, mechanisch hervorgerufenes Vibrieren wird nun zwar die Mitte des Ausschliffs gegen die Pinne hinstreben. Vorzugsweise günstig wirken z. B. die Längs-Schwankungen des Magnets gegen das seitliche Aufsitzen. Aber es ist keineswegs sicher, dass der schliessliche Ruhe-Punct des Magnets nun auch gerade der Scheitel des Ausschliffs sei. Im Gegenteil, die grösseren Abweichungen der (von den Variationen nachträglich befreiten) Magnet-Einstellungen zeigen deutlich an, dass die Pinne oft in einem anderen als dem Scheitel-Puncte angreift und damit einen unregelmässigen Betrag des Collimations-Fehlers hervorbringt. Diese Erscheinung tritt besonders häufig im ersten Declinations-Satz bei der jetzigen Anordnung — Umlegung des Magnets ohne Oeffnung des Gehäuses — ein: die durch den Instrumententransport veränderte Lage des Magnets gegen die Pinne wird erst im Laufe der Messungen wieder verbessert.

Zur Beurteilung der Grösse des Collimations-Fehlers werde der Angriffs-Punct der Pinne bezogen auf ein horizontales Axen System: eine Axe parallel der magnetischen Axe, die andere senkrecht dazu, also unterschieden, λ eine Längs-Abweichung, β eine Quer-Abweichung des Magnetruhe-Punctes vom Scheitel (S) der Ausschleifung.

Die Collimation der Spiegel-Normale gegen die magnetische Axe sei c, der Winkel, den sie mit der Horizontalen beim freischwebenden Magnet bildet, sei w; der horizontale Betrag der Collimation sei a, der verticale Betrag h. Dann bestehen die Beziehungen:

Digitized by Google

$$\cos c = \cos a \,.\, \cos h, \qquad (1)$$
$$\sin h = \sin c \,.\, \sin w, \qquad (2)$$
$$\tan A = \tan c \,.\, \cos w. \qquad (3)$$

λ. Der Aufhänge-Punct sei in der Magnet-Richtung um den Betrag ds, vom Scheitel der Ausschleifung verschoben.

Mit der Veränderung von ds bewegt sich die Spiegel-Normale parallel zu den Mantel-Linien eines Kreis-Kegels, mit dem halben Oeffnungs-Winkel (90-λ) und der Axe horizontal und senkrecht zur Magnetaxe.

Die Grösse A des Collimations-Fehlers für die Neigung H ergibt sich aus

$$\sin A = \frac{\sin a}{\cos H}, \qquad (4)$$

Für die Veränderung von A mit der von H kommt

$$\cos A \,.\, d A = \frac{\sin a \,.\, \sin H}{\cos^2 H}\, d H. \qquad (5)$$

Hier lässt sich A mit a, H mit h vertauschen, auch einmal cos H vernachlässigen, so dass man genähert hat

$$d a = \tan a \,.\, \tan h \,.\, d h, \qquad (6)$$

$$d a = \frac{a \,.\, h}{\rho^2} \,.\, d h. \qquad (7)$$

Bei einem Instrument mit festem Magnet-Spiegel war $a = 52'$, $h = 43'$; der Angriffs-Punct der Pinne war 2.8 mm über dem Schwerpunct. Die Verschiebung des Angriffs-Punctes der Pinne um 0.1 mm in Richtung der Magnet-Axe verursacht eine Höhen-Aenderung von

$$d h = \frac{0.1}{2.8} \,.\, 3438' = 123'.$$

Die Gleichung (7) ergibt für die Aenderung des Collimations-Fehlers den Betrag

$$d a = \frac{52 \times 43}{3438^2} \,.\, 123' = 0'.02,$$

also eine ganz geringe Grösse.

Die Längs-Verschiebung des Aufhänge-Puncts ist von unbedeutendem Einfluss auf den Collimations-Fehler: die Aenderung der Vertical-Intensität während der Messung braucht nicht berücksichtigt zu werden.

β) Der Aufhänge-Punct sei quer zur Magnet-Richtung um den Betrag $d s_2$ vom Scheitel der Ausschleifung verschoben.

Digitized by Google

Mit der Veränderung von $d s_1$ bewegt sich die Spiegel-Normale parallel zu den Mantel-Linien eines Kreis-Kegels mit dem halben Oeffnungs-Winkel c und der Axe parallel zur magnetischen Axe. Die Veränderung des Collimations-Fehlers mit der des Winkels w erhält man aus

$$\tan a = \tan c \cos w \qquad (3)$$

durch Differentiation, in Verbindung mit (1) und (2),

$$d a = - \tan h \,.\, \cos a \, dw, \qquad (8)$$

oder genähert, da $\cos a$ nahezu $= 1$,

$$d a = - \tan h \,.\, dw, \qquad (9)$$

$$d a = - \frac{h}{\rho} . \, dw. \qquad (10)$$

(Man kann die Ableitung auch am ebenen Dreieck ausführen.) Bei dem oben genannten Instrumente mit $a = 52'$, $h = 43'$ (also einer Spiegel-Collimation von $62'$, unter dem Winkel $w = 40°$ gegen a geneigt) bringt eine Quer-Verschiebung des Aufhänge-Punctes um den Betrag 0.1 mm, also $dw = 123'$, eine Aenderung des Collimations-Fehlers hervor, nach (10), um,

$$d a = - \frac{43}{3438} . \, 123' = - 1'.5,$$

— also einen erheblichen Betrag.

Mit dem oben genannten Instrumente erhielt der Verfasser Fehlbeträge bis zu $3'$, was einer seitlichen Verschiebung von 0.2 mm entspricht; das Hütchen war aus Saphir, das Magnet-System wog 10 g.

Die Quer-Verschiebung des Aufhänge-Puncts ist von bedeutendem Einfluss auf den Collimations-Fehler.

Man hat also bei der Construction dafür Sorge zu tragen, dass die Collimation des Magnet-Spiegels beseitigt werden kann, nicht nur in horizontalem, sondern vielmehr noch in verticalem Sinne.

Digitized by Google

ZUR BIBLIOGRAPHIE VON W. GILBERT'S "DE MAGNETE."

VON G. HELLMANN.

Vor einiger Zeit frug ein Fachgenosse bei mir an, welche Ausgabe von William Gilbert's grundlegendem Werke "De Magnete" die seltenste sei. Ich habe diese Frage nicht ohne weiteres beantworten können, sondern erst einige Nachforschungen darüber anstellen müssen, deren Ergebniss ich wegen der grossen Wichtigkeit und Seltenheit des Buches hier auch weiteren Kreisen mittheilen will.

Zunächst möchte ich betonen, dass es nur drei Ausgaben von Gilbert's Werk giebt: London 1600, Stettin (Sedini) 1628 und 1633. Die beiden letzten wurden von dem Stettiner Assessor *Wolfgang Lochmann* besorgt, einem grossen Verehrer der Gilbert'schen Lehren, die damals im Ausland mehr Anklang fanden, als in England selbst.

Die Annahme, dass es vier oder gar fünf verschiedene Ausgaben gäbe, die noch von Herrn *P. Fleury Mottelay* in der von ihm 1893 in New York besorgten englischen Uebersetzung eingehend besprochen wird, rührt nach meinen Nachforschungen offenbar daher, dass das "Allgemeine Europäische Bücher-Lexicon" von *Th. Georgi* (Leipzig 1742. Fol.) beim Artikel Gilbert folgende Angaben macht:

							Bog.	Thl.	Gr.
1600	Guilelmi	Gilberti de Magnetae, magneticisque corporibus f.				Londini	.....	2	.....
1628	.....	..... id. Libr.	"	"	4	Frf. Hallew.	36	.....	8
1636	.....	..... id. Libr.	"	"	4	Amst. Janson	36	.....	18
1633	.....	..... id. Libr.	"	"	4	Sedini	36	.....	8

Danach würde es schon vier Ausgaben (London 1600, Frankfurt 1628, Stettin 1633 und Amsterdam 1636) geben, und da auch eine Ausgabe von Stettin 1628 sicher bekannt war, so nahmen die Bibliographen das Vorhandensein von sogar fünf verschiedenen Ausgaben an.

Nun ist aber *Georgi's* Bücherlexicon durchaus keine zuverlässige Bibliographie, sondern ein von einem Buchhändler nach Bücherverzeichnissen und nach Messkatalogen zusammengestelltes Lexicon, das mehr practischen als wissenschaftlichen Zwecken dienen sollte.

Zunächst fällt schon auf, dass die Stettiner Ausgabe von 1628 von Georgi gar nicht erwähnt wird, wohl aber eine Frankfurter aus demselben Jahre. Damit hat es offenbar folgende Bewandtniss.

Von der ersten durch W. Lochmann besorgten Stettiner Ausgabe von 1628 giebt es zweierlei Exemplare; die einen haben auf dem in Kupfer geätzten Titel die Worte " . . . *Sumptibus*|*Authoris*|", die anderen sonst genau identischen Exemplare aber " . . . *Sumptibus* | *Joh. Hallervor-*

Digitized by Google

dij | ". Man wird demnach annehmen dürfen, dass Wolfgang Lochmann (auf dem Titel steht Lochmans) die Stettiner Ausgabe von 1628 auf seine eigenen Kosten hat drucken lassen, dass er aber einen Theil der Auflage an den Buchhändler *Johann Hallervord* sammt der Kupferplatte des Titels verkaufte, da er vermuthlich als Privatmann Schwierigkeiten hatte, das Buch abzusetzen. Der Käufer der Restbestände liess auf der Kupferplatte die Zeile "*Authoris*" in "*Joh. Hallervordij*" umändern und brachte die mit solchem Titel versehenen Exemplare auf der Frankfurter Messe zum Verkauf. Dieser Hallervord ist aber kein anderer, als der in Rostock ansässige Buchhändler Johann Hallervord (geb. 1581), dessen umfangreicher Verlag in 33 Jahren über 970 Werke aufweist. Die in Georgi's Bücherlexicon gemachte Angabe "Frf. Hallew." muss demgemäss nur als eine Messadresse aufgefasst werden.

Aehnlich dürfte es sich mit der dritten von *Georgi* verzeichneten Ausgabe verhalten. Der bekannte Amsterdamer Buchhändler *Janson* hat wahrscheinlich eine grössere Anzahl von Exemplaren der Ausgabe von 1633 erworben[1] und sie 1636 in Holland auf den Markt gebracht. Janson hat aber niemals ein besonderes Titelblatt dazu drucken lassen.

Es giebt also nur drei Ausgaben von Gilbert's De Magnete, nämlich London 1600, Stettin 1628 (zwei Varianten) und Stettin 1633.

Nach der Ausgabe von 1628 scheint grosse Nachfrage gewesen zu sein; denn es sind mir drei Exemplare bekannt geworden, in denen die 12 Tafeln fehlen. Dass diese nicht später abhanden gekommen sind, möchte ich aus dem alten, möglicherweise gleichzeitigen Einbande dieser Exemplare schliessen. Sie sind offenbar gleich defect in den Handel gebracht worden.

Diese Nachfrage hat auch vermuthlich den Assessor Lochmann dazu bewogen, 1633 eine zweite Ausgabe zu veranstalten, die auf den ersten Anschein nur eine sogenannte Titelauflage der von 1628 zu sein scheint, in Wahrheit aber einen wirklichen Neudruck darstellt. Die Auflage wird nunmehr absichtlich grösser gemacht worden sein, wodurch sich das häufigere Vorkommen der Ausgabe von 1633 gegenüber der von 1628 ganz ungezwungen erklärt.

Um die relative Seltenheit der drei Ausgaben von Gilbert's Werk festzustellen, habe ich die werthvollen Antiquariats- und Auctionscataloge, die man sich um ihres bibliographischen Werthes willen aufhebt, zu Rathe gezogen und dabei gefunden, dass die Ausgabe von 1628 weitaus am seltensten vorkommt.

Da es auch von Interesse sein dürfte, die enorme Preissteigerung kennen zu lernen, die Gilbert's Werk im Laufe der letzten 20 Jahre erfahren

[1] Das Erwerben oder Kaufen auf den Buchmessen bestand grösstentheils in einem Tauschgeschäft der Verleger unter einander. Man tauschte die gleiche Zahl Bogen des einen Werkes mit der eines anderen Werkes aus. Die Bücher selbst wurden nicht fertig broschirt, sondern meist in losen, ungefalzten Bogen nach Frankfurt und Leipzig zur Messe gebracht.

Digitized by Google

hat — da dieselbe in drastischer Weise den grossen Aufschwung des Studiums des Erdmagnetismus kennzeichnet —, lasse ich folgende Uebersicht von dem Vorkommen und dem Preise der drei Ausgaben hier folgen:

AUSGABE VON 1600.

Originalpreis in London, 1600	7 s. 6 d.
" " Frankfurt auf der Messe	2 Thaler.
Auction Roxburghe, London 1756	9 s.
" Lalande, Paris 1808	6 fr.[1]
" Van Swinden, Amsterdam 1824	2 flor. 50 c.
Catalog Maynard, London 1847	4 s. 6 d.[2]
Auction Arago, Paris 1854	15 fr.
" Libri, Paris 1857	5 fr.
Catalog Butsch, Augsburg 1865	5 Gulden.
" Quaritch, London 1881	28 s.
" Wesley, London 1885	3 £
" " " 1886	5 £ 5 s.
" " " 1890	6 £ 6 s.
" Calvary, Berlin 1897	120 Mark.
" Wesley, London 1898	8 £ 8 s.
" Koehler, Leipzig 1899	120 M.
" Muller, Amsterdam 1900	125 flor.
" Quaritch, London 1901	10 £ bis 18 £ 18 s[3]

AUSGABE VON 1628.

Originalpreis 1628	8 Groschen.
Auction Ch. Hutton, London 1816	Unverkäuflich.
" Van Swinden, Amsterdam 1824	3 flor.[4]
" Chasles, Paris 1881	20 fr.
Catalog Friedländer, Berlin 1885	20 M.
" " Berlin 1890	26 M.
" Quaritch, London 1895	11 £

AUSGABE VON 1633.

Originalpreis 1633	8 Groschen.
" in Holland 1636	18 Groschen.
Catalog Maynard, London 1847	6 s. 6 d.
" Friedländer, Berlin 1879	7 M. 50 Pfg.
" Brill, Leiden 1880	3 fl. 50 c.
Auction Chasles, Paris 1881	42 fr.
Catalog Friedländer, Berlin 1885	20 M.
" Macmillan & Bowes, Cambridge 1893	5 £ 5 s.
" Wesley, London 1898	4 £ 4 s.
" Friedländer, Berlin 1899	100 M.
" Quaritch, London 1900	5 £
" " London 1901	4 £ 4 s.

[1] Zusammen mit *Kircher's* Magneticum regnum und LE MONNIER'S Lois du magnétisme!

[2] Das Buch wird als "curious" bezeichnet!

[3] 18 Guineas wird für ein Exemplar gefordert, das dem Magnetiker *Wm. Barlow* gehört hat und dessen Autograph trägt.

[4] Zusammen mit *Leotaud's* Magnetologia.

Digitized by Google

Natürlich kommt die eine oder andere Ausgabe gelegentlich auch einmal zu wesentlich niedrigeren Preisen vor in den Catalogen von kleineren Antiquaren, die über die Nachfrage nach dem Werke nicht genügend orientirt sind. Die hier angeführten Preise dürfen aber als maassgebende gelten. Man ersieht aus ihnen, dass die grosse Preissteigerung, als Folgeerscheinung einer häufigeren Nachfrage, zu Anfang der achtziger Jahre des vorigen Jahrhunderts eingesetzt hat, d. h. in einer Zeit, wo durch die international vereinbarte meteorologisch-magnetische Forschung in den Polargebieten ("Polarjahr 1882–83") das Studium des Erdmagnetismus aufs neue eine mächtige Anregung erhalten hatte.[6]

Die Ergebnisse dieser kleinen Nachforschung sind also folgende:

1. Es giebt nur drei Ausgaben von Gilbert's Werk "De Magnete": Londini 1600, Sedini 1628 und Sedini 1633.

2. Von der Ausgabe Sedini 1628 giebt es zweierlei Exemplare mit etwas verschiedenem Titelblatt.

3. Die seltenste Ausgabe ist die Stettiner vom Jahre 1628, und von den beiden Varianten derselben diejenige, welche auf dem Titel die Worte trägt " . . . *Sumptibus* | *Authoris* | ".

BERLIN, im März 1902.

[6] Ganz ähnlich wie Gilbert's altem Werk ist es dem so viel jüngeren "Handbuch des Erdmagnetismus" von *Lamont* (Berlin 1849) ergangen. Die wenigen übrig gebliebenen Exemplare desselben wurden im "Polarjahre" verkauft, so dass das Buch, welches man früher für 2 — 3 M. haben konnte, jetzt allmählich den Werth von 50 — 60 M. erreicht hat.

Digitized by Google

PAUL PASSALSKIJ UND SEIN LETZTES ERDMAGNETISCHES WERK.

Von Professor Dr. E. Leyst.

Die erdmagnetische Wissenschaft verlor am 12/25. November 1900 durch einen plötzlichen Tod einen ihrer würdigsten Vertreter in Russland—*Paul Passalskij*. Ein reich begabter und äusserst thätiger Gelehrter ist nach kaum fünfjähriger, aber immense fruchtbarer Thätigkeit in ihm zu Grabe getragen worden, im Alter von nur 29 Jahren. Sein äusserer Lebensgang ist daher in nur wenigen Worten zu schildern.

Nach Beendigung des Gymnasiums in Kischinew bezog er die Universität Odessa, die er mit dem Grade eines Candidaten der Mathematik absolvirte, nachdem er für eine thermo-dynamische Arbeit von der Universität mit einer goldenen Medaille prämiirt worden war. Diese Arbeit war auch seine erste Druckschrift und umfasste über 200 Seiten. Er wurde zur Vorbereitung zu einer Professur bei der Universität belassen und da in demselben Jahre das magnetisch-meteorologische Observatorium der Universität Odessa eröffnet wurde, so wurde Passalskij von dem Director des Observatoriums, Professor Dr. Klossowskij, zum Beobachter ernannt. Zunächst waren es nur meteorologische Beobachtungen, die er auszuführen hatte, aber bald fand er im Kabinet der physikalischen Geographie einen alten magnetischen Theodolithen und unternahm eine Untersuchung desselben, worüber er eine besondere Abhandlung veröffentlichte. Hier zeigte sich bereits der gute Beobachter und scharfe Theoretiker.

Die reiche Begabung und die unermüdliche Thätigkeit Passalskij's lernte ich Sommer 1896 kennen, als ich auf Ersuchen der Direction den magnetischen Theil des Observatoriums in Odessa einrichtete und dabei von Passalskij unterstützt wurde. Es war uns beiden eine Freude zusammen zu arbeiten, denn Ermüdung war uns unbekannt. Diese vorzügliche Eigenschaft kam ihm auch sehr zu Statten bei der Untersuchung der Anomalie von Kriwoi-Rog, denn solche Arbeiten erfordern eine mit Sonnenaufgang beginnende und bis zum Sonnenuntergang ununterbrochen fortgesetzte Thätigkeit. Unsere gemeinsame Arbeit bei der Einrichtung des magnetischen Observatoriums in Odessa wurde unter dem Titel "Aufstellung der erdmagnetischen Variationsapparate" in Odessa im Jahre 1897 veröffentlicht. Die Leitung des magnetischen Theiles des Observatoriums übernahm Passalskij und führte sie bis zu seinem Todestage.

Im December 1897 beendete Passalskij sein Magister-Examen

Digitized by Google

und begann im nächsten Semester seine Vorlesungen an der Universität Odessa über Erdmagnetismus in der Eigenschaft eines Privat-Dozenten. Neben der practischen Thätigkeit fand er noch Zeit für die academische. Da aber für eine Professur in Russland, ausser der Candidatenschrift, noch zwei Dissertationen erforderlich sind, so musste Passalskij sich nach einem geeigneten Thema umsehen, das er aus dem Gebiete des Erdmagnetismus wählen wollte. Anfang 1898 war er noch unschlüssig, doch bald entschied er sich für die magnetische Anomalie in Kriwoi-Rog, die von vornherein vielversprechend war. Ich hatte bereits zwei Sommer die Kursker Anomalie untersucht und um unsere Beobachtungen, die ich von Kursk bis nach Kriwoi-Rog nach Süden ausgedehnt hatte, vereinigen zu können, verabredeten wir, uns in Otschkolowka zu treffen und durch gleichzeitige Beobachtungen unsere Instrumente zu vergleichen. Dabei erwies es sich, dass die geomagnetischen Gradienten so gross waren, dass wir auf 21 Meter Entfernung unglaubliche Differenzen fanden und einfache gleichzeitige Beobachtungen keine erwünschte Vergleichung zuliessen. In diesem Gebiete beobachtete Passalskij alle drei Elemente an 406 Puncten. Als er dann im darauffolgenden Winter an die Reduction auf bestimmte Epochen ging, stellte es sich nach den Erfahrungen von Professor Piltschikow und mir im Gebiete der Kursker Anomalie heraus, dass eine solche Reduction für Störungsgebiete höchst unsicher ist. Meine Variationsbeobachtungen vom Jahre 1897 im Kursker Gebiet ergaben für Orte mit grosser Inclination und kleiner Horizontal-Intensität ($I = 82° 2'$ und $H = 0.076$ c. g. s.) eine Amplitude der Declination, welche mehr als das Dreifache der normalen betrug, während umgekehrt auf ein Kilometer Entfernung (bei $I = 59° 7'$ und $H = 0.285$ c. g. s.) die Amplitude weniger als die Hälfte der normalen betrug. Um diese Verhältnisse in Kriwoi-Rog zu untersuchen, unternahm Passalskij im Jahre 1899 noch eine Fahrt in das Gebiet der grössten Störung und bestätigte meine Resultate.

Während Passalskij mit der Ausarbeitung seiner Beobachtungen vom Jahre 1898 beschäftigt war, unternahm er im Jahre 1900 bereits eine neue Arbeit, die magnetische Landesaufnahme der Halbinsel Krim. Der vorschnelle Tod hat ihn verhindert, sein neues Material (202 Puncte, davon 157 in der Krim) endgültig zu verarbeiten, aber eine vorläufige Uebersicht gab er mir in einem, einen Monat vor dem Tode abgefassten Brief, und diese Uebersicht hat ihm Anlass gegeben zu einigen Bemerkungen, die nach seinem Tode ohne nähere Begründung veröffentlicht wurden. Es handelt sich um die Abhängigkeit der Vertheilung des Erdmagnetismus von der Vertheilung von Land und Wasser. Die Beobachtungen auf der Halbinsel Krim zeigten keinerlei Anomalien, nicht mehr

Digitized by Google

als 10′ bis 15′. Dennoch hatten die Isoklinen keinen regelmässigen Verlauf, sondern die äusserste derselben verläuft fast parallel den Süd- und Westküsten, und die übrigen laufen dieser parallel. Ich glaube jedoch, dass eine Verallgemeinerung dessen auf den ganzen Erdball etwas voreilig ist. Die Bearbeitung des Beobachtungsmaterials von Kriwoi-Rog war Anfang October 1900 beendet und in die Druckerei gegangen, doch war es dem Autor nicht vergönnt, mehr als 5 Druckbogen zu erleben. Die übrigen 29 Druckbogen, die zahlreichen Karten und Zeichnungen blieben unerledigt und Dank den Bemühungen des Privat-Dozenten B. Weinberg in Odessa wurden sie nachher in kürzester Zeit veröffentlicht. In diese letzte Arbeit gingen denn auch viele Bruchstücke einer von Passalskij geplanten künftigen Arbeit über, die scheinbar eine zu knappe Fassung haben. Es sind eben mehr oder weniger ausführliche Notizen, in welchen nur die mathematischen Entwickelungen ausführlich und sehr lehrreich sind. Ja, schliesslich sind noch mehrfach Vermuthungen, Fragen, Aufgaben und dergl. abgedruckt, die nicht nur auf Geomagnetismus, sondern auf Geophysik überhaupt Bezug haben und auf den Leser anregend wirken. Doch gleichzeitig muss man um so mehr bedauern, dass eine so tüchtige Kraft der Wissenschaft so früh entrissen wurde.

Glücklicher Weise ist ein grosser Theil der Resultate zeitig geborgen worden und liegt vor uns unter dem Titel "Ueber die Vertheilung des Magnetismus auf der Oberfläche der Erde," Odessa 1901, in russischer Sprache, ohne Resumé in andern modernen Sprachen. — 547 Seiten, 17 Karten und 17 Zeichnungen. Das Werk zerfällt in 7 Kapitel, Zusätze (78 Seiten) und 1249 Nummern Litteratur-Nachweis (darunter 72 in russischer Sprache). Der Hauptinhalt betrifft die Anomalie in Kriwoi-Rog, während die übrigen Kapitel sich mit Fragen beschäftigen, freilich auf weitester Basis, die zur Hauptfrage in naher Beziehung stehen. Es sind kritische Betrachtungen, die ebenso gut selbstständige Arbeiten bilden können, hier aber, wie in allen umfangreichen Arbeiten, häufig in den Hintergrund treten. Man wird Vieles dort nicht suchen und daher ist es Pflicht des Referenten, auf solche Ausführungen besonders hinzuweisen, zumal das Original in einer den Erdmagnetikern wenig geläufigen Sprache geschrieben ist.

Im ersten Kapitel giebt der Autor eine allgemeine Uebersicht der magnetischen Landesaufnahmen grösseren oder kleineren Umfangs nicht nur für Europa, sondern auch für die übrigen Welttheile, für die Polarländer und für grössere Reisen, hauptsächlich seit den vierziger Jahren des vorigen Jahrhunderts. In dieser nach den Ländern geordneten Uebersicht sind nahezu 300 Quellen angegeben.

Digitized by Google

Das zweite Kapitel behandelt die Feldbeobachtungen und ihre Genauigkeit; mit viel Sachkenntniss wird die wahrscheinliche Genauigkeit zunächst an den Normalständen der Variations-Instrumente, da diese zur Reduction benutzt werden müssen, und dann weiterhin an den Differenzen in den Angaben verschiedener Theodolithe geprüft, und schliesslich betrachtet der Verfasser die thatsächlich erreichte Genauigkeit der englischen und der oesterreich-ungarishen Landesaufnahmen. Er findet, dass man über eine Genauigkeit der Declination und der Inclination von 2′ bis 3′ und der Horizontal-Intensität von 0.00005 bis 0.00010 c. g. s. nicht hinauskäme und zu dieser Annahme berechtigen ihn seine eignen 609 Beobachtungspuncte. Dann theilt der Verfasser Verschiedenes mit über die Praxis der Feldbeobachtungen und der sogenannten Reiseinstrumente. Man fühlt es dem Autor nach, wenn er sagt, dass jede entbehrliche Schraube des Instruments oder seiner Verpackung, die im Fahren zu Wagen bei schlechten Landwegen sich lösen kann, dem Beobachter viel Verdruss und Zeitverlust verursachen kann. Zum Schluss dieses Kapitels unterzieht der Verfasser das bereits seit 9 Jahren hängende Project der magnetischen Landesaufnahme in Russland einer sachgemässen Kritik und macht diesbezügliche Vorschläge.

In den folgenden 120 Seiten umfassenden Kapiteln werden die Reductionen der Feldbeobachtungen auf bestimmte Epochen sehr eingehend besprochen. Sehr werthvoll sind diejenigen Abschnitte, welche die Elimination des täglichen Ganges (Seite 107 bis 127) und die Aenderungen des Erdmagnetismus in verticaler Richtung (Seite 133 bis 182) behandeln, indem hier viel Neues geboten wird. Nachdem auf die seit Lamont gemachten Andeutungen über die Möglichkeit eigenartiger täglicher Variationen in den Gebieten starker Anomalien hingewiesen worden, werden die thatsächlichen Beobachtungen der neuesten Zeit herangezogen. Nachdem der Autor die Zahlenwerthe meiner Kursker Variations-Beobachtungen kurz mitgetheilt, giebt er eine vollständige Tabelle seiner eignen, freilich nur 10 Tagesstunden umfassenden Variations-Beobachtungen der Declination und Horizontal-Intensität an zwei etwa 3 Klm. von einander entfernten Puncten. Am Puncte *A* betrug die Horizontal-Intensität 0.043 c. g. s. und in *B* 0.464, also fast 11 Mal mehr. Die Amplituden betrugen:

	Punct *A*.	Punct *B*.
Declination	29′.2 (in Odessa 7′.6)	5′.0 (in Odessa 8′.3)
Horizontal-Intensität	0.00021 (in Odessa 0.00035)	0.00179 (in Odessa 0.00038)

Die Variationen der Declination in Kriwoi-Rog bestätigen vollkommen meine Kursker Resultate, während die Grösse der Ampli-

Digitized by Google

tude der Horizontal-Intensität mit anormaler grosser Intensität eine ganz unerwartete Erscheinung war. Dieses veranlasste den Verfasser diese Frage eingehend theoretisch zu untersuchen. Ausgehend von den v. Bezold'schen Vectordiagrammen und den einschlägigen Piltschikow'schen Erörterungen, untersucht der Verfasser, bei Scheidung der normalen und anormalen Quantitäten, den Einfluss von magnetischen Massen unter der Oberfläche der Erde auf die täglichen Variationen, vorausgesetzt, dass die magnetische Masse homogen sei. Geleitet von den Entwickelungen von Riecke, Beer, Neumann, Wassmuth und anderen gelangt er zu Formeln, welche die in Gebieten von Anomalien zur Beobachtung kommenden täglichen Variationen darstellen. Unter vereinfachenden Annahmen über die störenden Massen findet man Ausdrücke, welche eine befriedigende Uebereinstimmung mit den oben angeführten Beobachtungen zeigen. Auf diesem Wege wird nicht allein die grosse Amplitude der Horizontal-Intensität im Puncte *B* völlig erklärt, sondern auch erwiesen, dass die üblichen Reductionen auf bestimmte Epochen bei Beobachtungen in Gebieten starker Anomalien ganz illusorisch sind.

Vielleicht noch wichtiger ist der Abschnitt über Reductionen auf ein bestimmtes Niveau, wenn nicht in practischer, so doch in theoretischer Hinsicht. Bekanntlich hat Professor Liznar die sehr einfache Relation der verticalen Aenderungen

$$\Delta X,\ \Delta Y,\ \Delta Z \text{ der Componenten } X,\ Y,\ Z$$
$$\frac{\Delta X}{X} = \frac{\Delta Y}{Y} = \frac{\Delta Z}{Z} = \frac{3h}{R} = 0.00047\ h.$$

aus den Gauss'schen Formeln abgeleitet, wenn h die Seehöhe und R den Erdradius bezeichnet. Passalskij zeigt nun, dass dieses constante Verhältniss nicht statt hat und durch zu weitgehende Vernachlässigung der höheren Glieder entsteht. Nachdem er die Gauss'schen Formeln zweckentsprechend umgeformt und die Schmidt'schen Functionen R_m^n eingeführt, gelangt er zu folgenden Ausdrücken:

$$X_h = X_o - \frac{3\,X_o - a'}{R+h}\,.\,h$$

$$Y_h = Y_o - \frac{3\,Y_o - a''}{R+h}\,.\,h$$

$$Z_h = Z_o - \frac{3\,Z_o - a'''}{R+h}\,.\,h$$

wo a', a'', a''' Ausdrücke darstellen, die sich aus den Potentialformeln ergeben. Die nach diesen Formeln berechneten Zahlentabellen zeigen, dass $\Delta X/X$ u. s. w. durchaus nicht constante, nur mit der Höhe sich ändernde Verhältnisse darstellen, sondern sich mit allen

Digitized by Google

drei geographischen Coordinaten (ϕ, λ, H) ändern und von dem Liznar'schen Werth 0.00047k bis zu 94% abweichen können. Unter Theilung des normalen und anormalen Geomagnetismus in dem von mir angegebenen Sinn (normaler Geomagnetismus der Breite ϕ wird dargestellt durch diejenigen Glieder der Gauss'schen Entwickelung, welche nur die Coefficienten $G_{n,o}$ enthalten) leitet Passalskij getrennte Formeln für die Abnahme des normalen ($X\,\phi$) und des anormalen ($X\,a$) Geomagnetismus ab und findet Ausdrücke von der Form:

$$\Delta\, X_\phi = \frac{3\, X_{\phi,\,o} - a'\phi}{R + k}$$

$$\Delta\, X_a = \frac{3\, X_{a,\,o} - a'_a}{R + k}$$

wo $a'\phi$ Reihen mit den Coefficienten $G_{n,o}$ und a'_a Reihen mit $G_{n,m}$ und $H_{n,m}$ ($m > o$) enthalten. Die Grössen

$$\Delta\, X_a,\ \Delta\, Y_a \text{ und } \Delta\, Z_a$$

hat der Autor kartographisch dargestellt, aber nicht publicirt, weil sie den von mir veröffentlichen Karten X_a, Y_a und Z_a (No. 8, 2 und 9) ähnlich sind. Er weisst weiterhin darauf, dass die verticalen geomagnetischen Gradienten von derselben Ordnung sind, wie die horizontalen, wobei aber zu beachten ist, dass der anormale Theil des Geomagnetismus mit der Höhe schneller abnimmt, als der normale Theil. Dies besagt, dass mit zunehmender Entfernung von der Erdoberfläche die normale nur von der geographischen Breite abhängige Vertheilung mehr und mehr vorherrscht.

Der Verfasser begnügt sich jedoch nicht mit demjenigen Theil des anormalen Geomagnetismus, der durch die Gauss'schen Constanten bei beschränkter Gliederzahl darstellbar ist, sondern geht auch auf die verticalen Aenderungen in localen Störungsgebieten ein und löst auch diese Aufgabe, vorausgesetzt, dass die hier sich äussernden Kräfte ein Potential haben. Zum Schluss dieses Kapitels kommt der Autor nochmals auf die Liznar'schen Untersuchungen über die verticalen Aenderungen zurück und erörtert die Frage, ob die von Professor Liznar gefolgerten electrischen Ströme ausserhalb der Erdoberfläche berechtigt sind, und verneint dies, da die Liznar'schen Formeln für die gesetzmässige Verticalabnahme des Erdmagnetismus nicht streng genug sind.

Im fünften Kapitel unterzieht der Autor die verschiedenen Prinzipien bei der Bestimmung des "normalen" Erdmagnetismus einer eingehenden Betrachtung und behandelt dieselben nach den Arbeiten von L. A. Bauer, Tillo, v. Bezold und mir. Darauf behandelt er noch die kartographische Darstellung der Landesaufnahmen, besonders mit Rücksicht auf grosse Störungsgebiete.

Digitized by Google

Das sechste Kapitel behandelt nur die Beobachtungen von Passalskij, der grossen Anomalie in dem Eisenerz-Gebiet von Kriwoi-Rog. (Geogr. Breite 48° und östliche Länge von Greenwich 33°). Das Störungsgebiet ist verhältnissmässig nicht gross und untersucht wurden etwa 2000 □ Klm. Die Zahl der Beobachtungspuncte betrug 406 und demnach entfallen 5 □ Klm. auf eine Station. Die Anomalie äussert sich hauptsächlich in meist meridional gerichteten Streifen mit grosser Verticalcomponente; zu beiden Seiten treten grosse Horizontalcomponenten auf, die Declination auf der Westseite nach Ost und auf der Ostseite nach West ablenkend. Die Streifen fallen mit den Eisenerzlagerstätten, soweit sie blossgelegt sind, zusammen, setzen sich aber auch da noch fort, wo die Erze nicht an der Oberfläche liegen. Gegenden letzterer Art sind geologisch auch weniger bekannt und Passalskij ist der Ansicht, dass genauere geologische Aufnahmen eine bessere Uebereinstimmung ergeben würden und meint, eine magnetische Aufnahme müsste der geologischen vorausgehen. Wir wollen die extremen Werthe der Elemente aus diesem Gebiet hier anführen.

		Maximum.	Minimum.	Differenz.
Declination	D	102°44′ W.	179°56 E.	282°40′
Inclination	I	86° 5′	44°12′	41°53′
Horizontale Componente	H	0.7130	0.0548	0.6582 c. g. s.
Meridionale "	X	0.6370	—0.1278	0.7648 "
West "	Y	0.6250	—0.3233	0.9483 "
Verticale "	Z	1.7124	0.3548	1.3576 "
Ganze Intensität	W	1.7164	0.4002	1.3162 "

Ich gebe die Extreme nach den Zusammenstellungen von Passalskij selbst, bemerke aber, dass der eine der Puncte für Variationsbeobachtungen im Jahre 1899 den Werth H=0.043 c. g. s. hatte und mit diesem wächst die Differenz auf 0.670 c. g. s. Die Entfernung der Puncte mit den extremen Werthe X und Y beträgt 2 bis 3 Klm., die für Z und I, 55 Klm. Man findet bei Kriwoi-Rog magnetische Gradienten, die anderweitig unbekannt sind. Auf 42 Meter Entfernung ist die Declination um 116°37′ verschieden, oder um 2°.8 pro Meter. Auf 21 Meter Entfernung ändert sich die Inclination um 19°1′, die Horizontal-Componente 0.3609 c. g. s., die Y Componente um 0.458 und die Z-Componente um 0.529 c. g. s. Pro Meter findet man $\delta H = 0.0173$, $\delta Y = 0.022$ und $\delta Z = 0.025$ Vergleicht man diese angeführten extremen Werthe und die Gradienten mit den bekannten westeuropäischen und amerikanischen Anomalien, so findet man, dass die Anomalie in Kriwoi-Rog sie um das Zehnfache bis Hundertfache übertrifft. Was die starken Gradienten anbelangt, so erklären sie sich durch die streifenartige

Digitized by Google

Anordnung der Anomalien und Erzlagerstätten mit schroffen Uebergängen zu den einschliessenden Formationen und der Lage der Erzstreifen an der Oberfläche oder unmittelbar unter derselben. In dieser Beziehung übertrifft die Anomalie von Kriwoi-Rog sogar die Kursk'sche. Was aber absolute Werthe der Extreme und die Ausdehnung der Anomalie im Kursk'schen und den benachbarten Gouvernements anbetrifft, so steht sie noch unübertroffen da. Meine seit 1896 alljährlich fortgesetzten Untersuchungen haben in den 6 Jahren bei schachbrettartiger Vertheilung der 1523 Beobachtungspuncte, ohne nach extremen Puncten zu haschen, folgende Grenzwerthe geliefert:

	Maximum.	Minimum.	Differenz.
Declination:	360°	0°	360°
Inclination:	90°	39°8′	50°52′
Horizontale Intensität:	0.8560	0	0.8560 c. g. s.
Verticale Intensität:	1.8365	0.3713	1.4652 "

Sämmtliche Extreme im Kursk'schen Gebiet sind stärker abweichend, als in Kriwoi-Rog, nur das Minimum der Vertical-Intensität macht eine Ausnahme. Eine der Kursker Störungslinien hat eine Länge von mindestens 230 Klm., denn so weit liegt sie in dem von mir bereits untersuchten Gebiet. Demnach ist die Anomalie in Kriwoi-Rog besonders bemerkenswerth in Bezug auf die enorm grossen Gradienten.

Im siebenten, nicht ganz abgeschlossenen Kapitel, behandelt der Autor die Ursachen, welche locale Anomalien hervorrufen und giebt eine gedrängte Uebersicht verschiedener Erklärungsversuche. Es wird der Felsenmagnetismus kurz beleuchtet; dann werden die grösseren Anomalien betrachtet, ihre electrischen Erklärungsversuche von Naumann erwähnt und ablehnend erledigt; endlich wird der anormale Magnetismus des Erdballs betrachtet und zwar in Verbindung mit Isonomalen der Temperatur und der Vertheilung von Land und Wasser. Es sind hauptsächlich referirende Zusammenstellungen, die offenbar die Einleitung zu diesem Kapitel bilden sollten, welches aber nicht vollendet werden konnte. Einiges, was hierzu gehört, findet man im Anhang halb angedeutet. In demselben Anhang findet man Ableitungen für die Formeln zur Berechnung der Lage der störenden Massen unter der Erdoberfläche.

Das ganze Werk ist ein würdiges Denkmal, das der so vorzeitig Dahingeschiedene sich selbst gesetzt hat. Friede seiner Asche!

Moskau, Anfang März 1902.

Digitized by Google

CHRISTOPHER HANSTEEN.[1]

Christopher Hansteen was born in 1784 in Christiania, where his early youth was spent. He was educated at the Cathedral School, and graduated in 1802. The same year he went to Copenhagen to study, and at first chose the law as his profession. In this he did not succeed, however, as he had no taste for legal studies. After some time he became tutor to a young nobleman, and in 1806 master in mathematics at the grammar school at Fredericksborg.

It was here that Hansteen chanced to take up the study of terrestrial magnetism, which was to be the commencement of his important life-work. The occasion was given by a large globe, on which, near the South Pole, were marked two magnetic regions, towards which the compass needle was said to point. This so astonished and interested Hansteen that he immediately had to assure himself of its correctness by studying the data upon which the mapping out of these regions was based, which, in this case, were those resulting from Cook's second voyage of discovery, when he sailed round the South Pole. Hansteen drew a map, with the aid of the observations made on this expedition, of the various positions of the needle, and arrived at a conclusion which accorded with the globe respecting the above-mentioned magnetic regions. Hansteen then went further. He wished to see whether, from the known observations of the directions of the compass needle in the northern hemisphere, he could also discover similar regions near the North Pole. His idea was, that the observed facts might possibly be explained by two magnets inside the Earth, and that it only remained to prove the existence of their four poles.

In 1811, Hansteen received an incentive to publish his temporary results, in the offer by the Royal Scientific Society in Copenhagen of a prize for the best essay on the subject: "Can all the magnetic phenomena of the Earth be explained by a single magnetic axis, or must we assume that there are more than one?"

In 1812, Hansteen sent in an essay on the above subject, and won the prize. He did not, however, get his paper printed, owing to the "disturbed condition of the pecuniary affairs of the country." It was not until 1819 that the treatise was published in an enlarged form, and in a German translation, by the aid of King Carl Johan. The immediate result of Hansteen's first victory, however, was his appointment in 1814 by King Christian Fredrik as lecturer in applied mathematics at the Christiania University, and subsequently, in 1816, as professor.

Henceforth he was able to pursue his magnetic studies with greater

[1] A translation procured by Professor Mohn of Professor Birkeland's biographical sketch of Hansteen in Jäger's "Litteratur Historie." To Professor Mohn the Editor is also indebted for securing the copy of Hansteen's last photograph, from which the reproduction in this Journal has been made, as also for the autograph taken from a letter written in 1859.—ED.

Digitized by Google

activity, as he was enabled to undertake the necessary journeys for collecting observational data for building up a theory of the Earth's magnetism. On the most important of these journeys, in Siberia, 1828–30, he was accompanied by Lieutenant Due, R. N., after the Storthing, in 1827, had with great liberality voted the necessary means, in accordance with the government bill brought forward through the warm interest shown by the king in Hansteen's plans. The details of this journey and its scientific results were not put together until 1859, in his interesting "Reminiscences of My Travels," and in 1863, in a long scientific treatise in German.

After his return from Siberia, where important results were obtained, Hansteen tried with unwearying zeal to link together and extend his series of observations, always with the idea in mind of establishing his hypothesis of the two magnetic axes, and of giving the theory such a mathematical form that the magnetic condition at any particular place on the Earth could be calculated. In this, however, he encountered great difficulties, which he never overcame. It appears that he himself had a presentiment of this, and that he hoped for some one else, "who would be endowed with greater strength in analysis, and a clearer vision."

This "some one else" with the clearer vision had not to be waited for long. At that very time he was already drawn to the same problems as Hansteen by the latter's energetic investigations. This was the famous mathematician, Gauss, in Göttingen.

Hansteen has been mentioned above only as a physicist. He was also, however, astronomer and meteorologist, but as such accomplished less, for one reason—because he was nearly fifty years of age before the new observatory could be used, and the old one was merely a shed. Among the best known of his astronomical works is his simple method of determining time (vertical of the pole star) and his fixing of the day of the battle of Sticklestad by the solar eclipse that took place at the time.

Hansteen also contributed frequently to Norwegian weekly and daily papers. His style was particularly clear and easy, full of humor and satire.

In addition to his posts as teacher at the University and director of the Observatory, Hansteen was occupied with several other objects. He was master in mathematics and astronomy at the military academy from the time of its erection, and was also director of the geographical survey, member of the board of inspectors of weights and measures, etc. In 1823, in connection with a few others, he founded the "Magazin for Naturvidenskaberne."

During the prosecution of his untiring labors, Hansteen received numerous proofs of the gratitude of his contemporaries, in the shape of distinctions both from State powers and from the scientific world abroad.

He died at the Observatory on April 15, 1875, and was buried at the expense of the University, the funeral procession starting from the aula of that building on the 21st of the same month.

Digitized by Google

PROFESSOR MAX ESCHENHAGEN: HIS LIFE AND WORK.[1]

By W. G. Cady.

In the life of Max Eschenhagen the world has a notable example of sterling ability winning its way through successive stages to a position of eminence and responsibility. He was born October 22, 1858, in Eisleben, and at the age of twenty-two took the doctor's degree at Halle, working chiefly in mathematics and physics. For the next two years he was employed in teaching. In 1883 he was appointed to a position on the German Polar Commission, and began what proved to be his life-work—the study of terrestrial magnetism. Until 1886, Eschenhagen was occupied with the reduction and publication of the observations from the polar expeditions at Kingua-Fjord and South Georgia; he was then for a year connected with the German Naval Observatory (Deutsche Seewarte), and in 1887 became an assistant in the Observatory at Wilhelmshaven. Two years later he was appointed an observer in charge of the new Magnetic Observatory at Potsdam and Chief of the Magnetic Division of the Prussian Meteorological Institute.

In this appointment Eschenhagen's greatest wish was fulfilled; and surely no better choice could have been made, for under his directorship the Potsdam Observatory assumed a front rank. The remainder of his life was spent here, working with untiring enthusiasm on all that concerned his chosen subject. As a director, he was strict and exacting, satisfied only with the best of which his subordinates were capable, yet quick to appreciate their merits. It was his ambition to make the Potsdam Observatory complete in every detail: to attain the highest possible precision in all departments of work and by intelligent examination of results to come closer to the fundamental truths of the Earth's magnetism. He was keen to detect instrumental errors, and ingenious in his means to avoid them. He firmly believed in the principle of making magnetic observations—both absolute and variation—in duplicate with instruments of widely different construction. His work on the observations of the "polar year," 1882–83, had given him excellent opportunity to compare the results from different instruments and under varying circumstances; and this experience bore fruit in later years.

He made a special investigation of the sources of error in the Lamont vertical force variometer and of the question regarding the dimensions and moments of magnets in relation to the deflection distances.

But Eschenhagen's most important contribution, and that which has made his name most widely known, is his sensitive, portable magnetic

[1] A résumé of papers by Prof. von Bezold (Deutscher Reichs-Anzeiger u. Kgl. Pr. Staats-Anzeiger, Nov. 22, 1901), and A. Nippoldt (*Naturw.* Rundschau, Jan. 30, 1902). A portrait of Professor Eschenhagen appeared in the December (1901) issue.

Digitized by Google

variometer for photographic registration, an instrument found in many magnetic observatories. In it we have the finished result of his desire for increased precision—an instrument not only unsurpassed for the accuracy with which it makes the usual daily record, but capable of magnifying its time-scale and sensitiveness many times when desired for special purposes. Not the least merit of the Eschenhagen variometer is the fact that it is the only instrument of its kind portable enough to be adapted for field use. The instrument has already been described in this Journal (see references below). It has proven itself admirably adapted, not only to the scientific work at fixed magnetic stations, but also to such temporary purposes as special observations on polar and eclipse expeditions, investigations on the effect of electric tramways, etc.

One of the earliest and most important uses of the Eschenhagen variometer was shown by the inventor himself in his investigations on "elementary magnetic waves" of small amplitude and period. These are becoming more and more an object of study and comparison between different stations, and are one of the principal sources from which we may expect light to be thrown upon the secrets of terrestrial electromagnetism. Eschenhagen was quick to grasp the importance of the "Elementarwellen;" he instituted series of simultaneous observations between widely remote stations, in the effort to determine the law that governs the phenomenon.

This leads us to the magnetic observations in connection with the Antarctic expeditions of the present year, in the planning of which Eschenhagen was a prime mover. The "International Program" appeared recently in this Journal, and it is a significant tribute to Eschenhagen's memory that, as the term-days come and go, observers all over the globe can feel that it is his genius that helped shape the policy of the work, and, in the great majority of cases, furnished the instruments in use.

Mention should also be made of the numerous other lines of activity in which Eschenhagen was at one time or another engaged, as, for example, his investigations on the effect of earthquakes upon magnetic instruments, on magnetic observations at distances above and below the surface of the Earth, the magnetic survey of Prussia, and numerous reviews for scientific journals.

His mind was restlessly active, quick to catch a hint from one line of research and transplant it into another. Even the suffering and ill-health that attended the last months of his life could not subdue his enthusiasm in his profession. His strong, true character and the Christian earnestness of his life commanded the respect of all who knew him. Throughout his all too brief career he remained true to his motto:

"Klarheit im Plan, so fang ich's an;
Fest im Vollbringen, so wird's gelingen."

Digitized by Google

So ist's auch gelungen, and the brilliant magnetician has left behind him a record of which his countrymen may well be proud.

Following is a list of Eschenhagen's leading publications. Those suggested by his work on the Polar Expedition of 1882–83 are cited first:

1. Die erdmagnetischen Beobachtungen im System der internationalen Polarforschung, 1882–83, Ann. der Hydrogr. etc., 1887, Heft 4.

2. Einige Resultate der erdmagnetischen Stationen im Systeme der internationalen Polarforschung. (Vortrag, gehalten auf dem 7. Deutschen Geographentag zu Karlsruhe.)

3. Erdmagnetismus. (Aus "Anleitung zur Deutschen Landes- und Volksforschung.")

4. Ueber das Lamont-Weyprecht'sche konstante Aenderungsverhältniss der Variationen der erdmagnetischen Horizontal-Intensität und der Inclination. (Deutsches Polarwerk.)

5. Ueber die Ablenkungskonstante bei den absoluten Bestimmungen der Horizontal-Intensität des Erdmagnetismus mittels des Lamont'schen magnetischen Theodoliten. (Deutsches Polarwerk.)

6. Die Lage der erdmagnetischen Pole in Beziehung zur Verteilung von Land und Wasser auf der Erde. Petermann's Mitteilungen, 1888, Heft 5.

7. Ueber die Verbesserungen, welche an den zu erdmagnetischen Beobachtungen dienenden Instrumenten auf Grund der an Deutschen Stationen von 1882–83 gewonnenen Erfahrungen auszuführen sind.

The following papers (No. 8–13) were published by him during his activity at Wilhelmshaven:

8. Absolute Bestimmungen der horizontalen Intensität des Erdmagnetismus zu Wilhelmshaven.

9. Erdmagnetische Beobachtungen zu Wilhelmshaven. (Archiv der Deutschen Seewarte, XVI, 1893.)

10. Einige magnetische Beobachtungen im Nordseegebiet. (Ann. der Hydrogr. etc., 1888, Heft 1.

11. Beeinflussung der magnetischen Registrirapparate in Wilhelmshaven, durch das Erdbeben in Spanien, 25. Dezember 1884. (Meteorol. Zeitschr., Februar 1885.)

12. Bestimmung der erdmagnetischen Elemente an 40 Stationen im nordwestlichen Deutschland. (Herausgeg. von dem hydrographischen Amt des Reichs-Marine-Amtes.)

It is probable that Eschenhagen was concerned in the anonymous contribution to the Ann. d. Hydrogr. etc., XVII, 1889, Heft 5, entitled:

13. Untersuchungen am Manganstahl bezüglich seiner magnetischen Eigenschaften, angestellt auf dem kaiserlichen Observatorium zu Wilhelmshaven.

While in charge of the Potsdam Magnetic Observatory he published the following papers:

Digitized by Google

14. Einige Bemerkungen zur Aufzeichnung der Variationen des Erdmagnetismus. Meteor. Zeitschr., Dezember 1892.

15. Das Erdbeben in Japan am 27. Oktober 1891. Astron. Nachr. 3067.

16. Erdmagnetismus und Erdbeben. Sitzungsb. d. Acad. der Wiss., Berlin, 1894, XLVI, 22. November.

17. Gewitter bei Potsdam am 30. Juni 1891. Meteor. Zeitschr., September 1891.

18. Magnetische Deklination zu Potsdam. Meteor. Zeitschr., Juni 1892.

19. Bestimmungen der erdmagnetischen Elemente im Togogebiet, 1892 und 1893, durch Dr. Gruner. (Mittheilungen aus den deutschen Schutzgebieten, Band VII, 1894, H. 1.)

20. Ueber ein Instrument zur Demonstration und Beobachtung der Variationen der magnetischen Deklination. (Zeitschr. für den physik. u. chemischen Unterricht, Jahrg. VIII, H. 5, 1895.)

21. On some Improvements in Magnetic Instruments. Extract from Part II of the Report of the Chicago Meteorological Congress.

22. Ueber schnelle, periodische Veränderungen des Erdmagnetismus von sehr kleiner Amplitude. Sitz. d. Acad. der Wiss. Berlin, 1897. XXXII. *Cf.* The Elementary Pulsations of the Earth's Magnetism. Terr. Mag.

23. Magnetische Untersuchungen im Harz. Forsch. zur deutsch. Landes- u. Volkskunde, Band XI, H. 1. Vergl. das Referat dazu von Putnam, Terr. Mag., Vol. III, No. 2.

24. Ueber telephonische Uhrvergleiche. (Astron. Nachr. 3628.)

25. Ueber die Bedeutung magnetischer Beobachtungen im Ballon. (Ref. von Dr. Arendt in Zeitschr. für Luftschiffahrt und Physik der Atmosphäre. September/October 1898.)

26. Ueber Quecksilberthermometer und Fernbeobachtung durch elektrische Uebertragung. (Zeitschr. für Instrumentenkunde, 1894, Nov.)

27. Ueber erdmagnetische Intensitätsvariometer. (Verhandlg. der Deutschen physik. Gesellsch., Jahrg. I, No. 9.) *Cf.* Magnetic Intensity Variometers. (Terr. Mag., Vol. V, No. 2.)

28. Erdmagnetische Observatorien und elektrische Bahnen. (Terr. Mag., Vol. III, No. 2.)

29. Ueber Simultan-Beobachtungen erdmagnetischer Variationen. (Terr. Mag., Vol. I, No. 2.)

30. Ueber einige Probleme des Erdmagnetismus und die Nothwendigkeit einer internationalen Organisation. (Terr. Mag., Vol. IV, No. 2, June 1899.)

31. Ueber die Einrichtung stationärer und temporärer magnetischer Observatorien. (Terr. Mag., Vol. IV, No. 4.)

32. Ueber eine neue Form der Lloyd'schen Wage. (Terr. Mag., Vol. VI, No. 2.)

Digitized by Google

THE PROPOSED MAGNETIC RESEARCHES OF THE NORWEGIAN POLAR STATIONS IN 1902–1903.

KR. BIRKELAND.

As leader of the expedition started by the Norwegian government for the study of Earth-magnetism, Boreal Lights, and Cirrus-clouds, I beg to state that during the time from August 1, 1902, until June 30, 1903, four Norwegian Stations will be erected, viz.: at Bossekop (Finmarken), at Dyrafjord (Iceland), at Aksel-Island (Spitzbergen), and Matotschkin-Schar (Novaja-Zemlja).

At these four stations the three magnetic elements will be registered photographically. To this effect registering instruments will be employed like those used by the contemporary Antarctic Expeditions. The three elements will also be determined absolutely. The term observations stipulated by the Antarctic Expedition will also be carried through at these stations.

The special subjects prosecuted by our expedition, and for the fulfillment of which we solicit your kind support, are: The determination of the cause and progress of different magnetic perturbations, as discussed by me in my report: "Expédition norvégienne de 1899–1900 pour l' étude des aurores borèales. Résultats des recherches magnétiques."

For the attainment of this, it is desirable first and foremost that in the usual daily registrations the time be ascertained as exactly as possible, and then that rapid registration take place on the following term-days:

Greenwich time:

1902	December	2,	from	9—11	P. M.				
	"	3,	"	9—11	"				
	"	4,	"	9—11	"				
	"	5,	"	9—11	"				
	"	6,	"	9—11	"				
	"	7,	"	9—11	"				
	"	8,	"	9—11	"				
1903	January	2,	from	11	P. M.	to	January	3, 1	A. M.
	"	3,	"	11	"	"	"	4, 1	"
	"	4,	"	11	"	"	"	5, 1	"
	"	5,	"	11	"	"	"	6, 1	"
	"	6,	"	11	"	"	"	7, 1	"
	"	7,	"	11	"	"	"	8, 1	"
	"	8,	"	11	"	"	"	9, 1	"
1903	February	3,	from	1—3	A. M.				
	"	4,	"	1—3	"				
	"	5,	"	1—3	"				
	"	6,	"	1—3	"				
	"	7,	"	1—3	"				
	"	8,	"	1—3	"				
	"	9,	"	1—3	"				

If a station where rapid registration is not possible wishes to take part in these observations, this can be done, by observing with a very sensitive variometer the points and times of reversion.

Digitized by Google

Single readings at regular intervals would, as a rule, afford no contribution toward the solution of the question.

With rapid registration two time marks controlled by chronometer should be fixed.

I may mention that this appeal for co-operation in magnetical researches has been sent to numerous magnetic observatories.

Concerning the cirrus-observations, the matter of interest is only the "cirrus radiation," formerly quoted as "polar-bands" (P. B.)

In its typical appearance, this phenomenon seems to be limited to the highest clouds, as cirrus, cirro-stratus, and cirro-cumulus.

To obtain a happy solution of this task, it is absolutely necessary to get the requisite facts from the largest number of points of observation distributed as widely as possible over the whole Earth.

In the first place it is most important to fix the direction in which these reciprocally parallel "bands" run. To obtain this result the easiest and surest way is the observation and notation of the two points of convergency, situated on either side of the horizon.[1]

If, however, these points of convergency are not developed at all, or only partly developed, the direction may be at once determined by observing bands not more than 20° from the Zenith. Besides, the width of a single band ought to be estimated, in lunar-diameters.

The determination of the direction of propagation and of the absolute or relative speed of the particles of the clouds appears less important to begin with.

Now, concerning the hours of observation, it would, of course, best serve the present object if the different observers would uninterruptedly watch the heavens with regard to cirrus radiation, even a passing apparition being sometimes of importance. But as such an intense observation would incur too great difficulties, it may be generally sufficient for the observers to test the phenomenon in the way described at the ordinary fixed periods.

On the other hand, it would be most useful if all stations would make observations at closer intervals on the so-called magnetic term-days (the 1st and 15th of every month), for instance, every two hours, and also watch as closely as possible the development of the bands. This is especially to be recommended when the cirrus radiation is very clear and brilliant.

I must here mention that a similar application, concerning observation of clouds is also sent to a great number of meteorological stations.

Christiania, May, 1902.

[The Superintendent of the Coast and Geodetic Survey, Mr. O. H. Titmann, has directed that the Coast and Geodetic Survey Magnetic Observatories co-operate with Prof. Birkeland in the plan of magnetic work outlined above. L. A. BAUER,
Chief of Division of Terrestrial Magnetism.]

[1] Here an accuracy of 5° seems to be satisfactory. The theodolite that may be used requires no telescope, a diopter being sufficient.

Digitized by Google

NOTES

7. *M. T. Moureaux* has been appointed to succeed the late *M. Renou* as director of the Parc St. Maur Observatory.

8. *It is expected that the new magnetic Observatory at Buitenzorg, near Batavia*, will soon be ready, so that the magnetic work in this locality can be resumed.

9. *Errata.*—In der Abhandlung: "Messungen des electrischen Potentialgefälles auf Spitzbergen und Juist," von Julius Elster, ist die Correctur nicht rechtzeitig eingetroffen. Hierdurch sind folgende Druckfehler stehen geblieben: p. 10, 6te Zeile von unten, statt "Am 6ten" lies "Aus sechs;" p. 11, 5te Zeile von oben, statt "reiner" lies "seiner." Die Tabelle, p. 11, ist durch folgende zu ersetzen:

Zeit, ...	9_a	10_a	$10\frac{1}{2}_a$	11_a	12_m	1_p	2_p	3_p	4_p	5_p	6_p	7_p	8_p
Potential gradient, ...	476	500	765	720	656	449	561	459	656	800	900	462	459

P 13, Im Citat 1) statt, "Wien Ber. Bd. 51" lies "Wien Ber. Bd. 101;" p. 14, Im Citat unter 1 statt, "Wien Ber. Bd. 49" lies "Wien Ber. Bd. 99."

10. *Magnetic Survey Work in Mexico.*—Magnetic work will be included in the operations of the Geodetic Commission of Mexico, so that within a short time the necessary data for the construction of magnetic charts will be on hand.

11. *Magnetic Survey of New Zealand.*—In Appendix VI of the Report of the Department of Lands and Surveys of New Zealand for the year 1900–1901, Mr. C. Coleridge Farr gives an account of the progress of the magnetic survey of the Colony. The previous year had been devoted to obtaining a general idea of the distribution of magnetism in the Middle Island by means of observations made at numerous places along the coast. During the year covered by the report Mr. Farr, with the assistance of H. F. Skey, carried on a similar campaign on the North Island, making magnetic observations at seventy-three stations scattered along the west and north coasts from Cook Strait to Bay of Plenty. North of latitude 38° the stations are close enough together to make it possible to draw the isomagnetic lines with some degree of accuracy. They show a large magnetic disturbance, which appears to follow the course of the Thames, and is stated by Captain Hutton "to agree beautifully with the geology of the district," there being a line of igneous rocks running in the direction of the disturbance.

Digitized by Google

The highly magnetic effect of iron sand is well illustrated at Mokau Heads, and, in fact, all along the west coast it is necessary to keep some distance from the coast line to get free from its influence. The effect of Mt. Egmont, a large isolated volcanic cone, is small, but appears to be that of a magnet with its north pole uppermost. D. L. H.

12. *Magnetic Observations in Brazil.*—In No. 7 of the "Boletim Semestral"[1] of the Navy Department of Brazil are published the results of the meteorological and magnetic observations in Brazil for the six months from April to September, 1900, made under the direction of Lieutenant Commander Americo Silvado. The magnetic observations are confined to Rio De Janeiro, and consist of declination on twenty or more days each month, inclination once a week, and horizontal intensity once a month.

This publication contains, also, a table giving the results of Dr. Vogel's magnetic observations at fourteen stations in Brazil in 1887, taken from the "Meteorologische Zeitschrift" for March, 1898,[2] and a description by Commander Silvado of some improvements recently made to the Elliott magnetometer (Kew model) belonging to the Brazilian Government.

To eliminate the possible source of error in declination due to the interposition of glass between the reading telescope and the magnet, an attachment in the shape of a truncated cone is fastened to the telescope end of the magnet box. A cylindrical tube just large enough to fit over the object end of the telescope slides in the small end of the truncated cone. When magnet box and telescope are in place the tube is pulled out until it fits over the end of the telescope. To enable the observer to determine his azimuth without an accurate knowledge of the local mean time, a vertical circle with eccentrically mounted telescope and counterpoise has been provided, so arranged as to be attached to the base of the magnetometer when the magnet box has been removed. This attachment also does away with the use of the mirror in azimuth observations. These improvements, though less radical, are along the same lines as those introduced in the Coast and Geodetic Survey magnetometers made in 1892 (see T. M. for March, 1900). D. L. H.

13. *Magnetic Observations in the Vicinity of Hudson Bay.*—In the Annual Report of the Canadian Department of the Interior for the year 1900–1901 (Ottawa, 1901) appears the report of an exploratory survey between Great Slave Lake and Hudson Bay, made by J. W. Tyrrell, D. L. S. in 1900.

The party was provided with a prismatic compass, a solar compass, and a dip circle arranged for the determination of relative total intensity. On page 133 of the report are given the results for declination at forty-five stations, but no values of dip or intensity.

[1] Boletim Semestral, N. 7. Ministerio da Marinha, Rio de Janeiro, 1901.

[2] Given also in TERRESTRIAL MAGNETISM for March, 1900.

Digitized by Google

Some account is given of earlier explorations in the same region, among them one by J. Burr Tyrrell, who, during the years 1893–1894, explored the Doobaunt, Kazan, and Ferguson Rivers. His report, contained in the Annual Report of the Geological Survey of Canada for 1896, gives values of the magnetic declination at several places along his route as follows:

Place	Date	Latitude	Longitude	Declination
Theitaga Lake, middle of w. shore, .	1894 July	59° 35′.7	101° 26′	21° E
Grassy portage, ...	1894 Aug.	59 58 .6	101 46	23 E
Ennadai Lake, ...	1894 Aug.	61 07	101 12	26 E
Angikuni Lake, ...	1894 Aug.	62 14 .2	100 11	24½ E
Kazan River, ...	1894 Sept. 1	63 07 .8	97 04	20¾ E

The longitudes were scaled from a map which accompanies the report.

Attention may be called to the second Hudson Bay expedition, under the command of Lieutenant A. R. Gordon, R. N. The party was provided with the variation instruments which had been used by Captain Dawson at the International Polar Station at Fort Rae, as well as an Elliott magnetometer and a Barrow dip circle. A magnetic observatory was established at Stuparts Bay Station, in latitude 61° 34′ 23″ and longitude 71° 31′ 42″, where eye readings of the variation instruments were made every four hours from September, 1884, to August, 1885, in addition to numerous determinations of the absolute values of the three elements. Some results were obtained at half a dozen of the other places visited by the party. D. L. H.

14. *Disturbance of the Compass on the North Coast of the Gazelle Peninsula (New Pommerania).*[1]—According to a report from H. M. S. *Möwe*, commanded by Captain Carl Schönfelder, October, 1901, the disturbance of the compass was experienced on the north coast of the Gazelle Peninsula in south latitude 4° 11′.9 and in east longitude 151° 41′.9, while making magnetic observations. It was noticed that when the magnet was brought in contact with the sand that a number of particles clung to the poles. The beach consisted apparently of black sand, mixed quite profusely with iron particles for a distance as far as was observed, about one kilometer. The deflection and the oscillation observations were influenced to a marked degree by these iron particles.

15. *The résumé of the magnetic observations made during the total solar eclipse, May 17–18, 1901*, can not be published until next issue on account of the late arrival of necessary data. L. A. B.

[1] Extract from Annalen der Hydrographie und Maritimen Metorologie, p. 160, 30ter Jahrgang, 1902.

Digitized by Google

ABSTRACTS AND REVIEWS

PAPERS ON ATMOSPHERIC ELECTRICITY.

Ueber die Anwendung der Lehre von den Gas-Ionen auf die Erscheinungen der Atmosphärischen Electricität, by Prof. Dr. Hans Geitel. Braunschweig, F. Vieweg & Son, 1901.

Recherches sur la Radioactivité Induite par l'air atmosphérique, by J. Elster and H. Geitel. Extrait des Archives des Sciences phys. et. nat., Feb., 1902.

On the Ionization of Atmospheric Air, by C. T. R. Wilson, Proc. Roy. Soc Vol. LXVIII, pp. 151–161, May, 1901. Also reprinted in "Monthly Weather Review," April, 1901, p. 139.

These few titles will serve to show the activity prevailing among foreign investigators in connection with the study of atmospheric electricity. Of the work of Elster and Geitel and also of C. T. R. Wilson single extracts can give but a poor idea, as nearly every month some new development in their experimental work is brought forward.

Professor Geitel's paper on the application of the laws governing the ions to the phenonema of atmospheric electricity is a very valuable and compact statement of what has been done thus far in the effort to account for the origin of the electrical charge of the atmosphere. It is remarkable, as Professor Geitel says, that this problem—one of the oldest in the domain of electrical knowledge—should still be so far from a satisfactory explanation. For nearly a century and a half, with the electrical nature of thunderstorms clearly comprehended and extended series of observations and measurements of the potential differences between earth and atmosphere available, we have not been successful in our attempts to explain the origin of these electrical fields. With every new achievement in electrical science some new view has been brought forward, and thus we have had in succession, following the older theories, unipolar induction of the earth's magnetism, photo-electric influence of sunlight, thermo-electric processes in the atmosphere and Röntgen ray effects. The opportunity was given to Geitel and his colleague Elster to discuss the bearing of the modern views of ionization and the electrical behavior of gases in connection with atmospheric electricity, and this Geitel has done most successfully. Not the least valuable part of the book for the worker is the handy reference list of recent contributions on these subjects.

In the paper upon induced radio-activity, Elster and Geitel attack the problem of inducing upon a conductor effects similar to those produced by a bombardment of ions. The term ion is employed to designate the small gaseous carrier of an electrical charge, which has become such by elevation of temperature, chemical action or by the influence of Röntgen rays. Adopting

Digitized by Google

this view, the conductivity of the air becomes a function of the quantity and mobility of the free ions contained therein. The results of numerous experiments are given, showing that an electrified conductor exposed in various ways in the dark and in daylight may lose its charge by the action of positive and negative ions.

Wilson in his paper on the Ionization of Atmospheric Air supplements his previous papers on the behavior and positively and negatively charged ions as nuclei on which water vapor may condense. It seemed advisable to determine whether a certain degree of ionization might not be a normal property of air. The principal results arrived at as stated by the author are:

1. That ions are continually being produced in atmospheric air (as is proved also by Geitel's experiments), and

2. That the number of each kind (positively and negatively charged) produced per second in each cubic centimeter amounts to about twenty.

A. McADIE.

LOSS OF LIFE IN THE UNITED STATES BY LIGHTNING.[1]

Several bulletins upon Lightning have appeared during the past five years, bearing the imprint of the Weather Bureau. The subject is one that will be always interesting. Since the time of Franklin the origin of the electricity of the air and the true reason for the sudden development of the electrical energy of thunder clouds have been subjects of much earnest inquiry and considerable speculation. Frankly, we seem yet to be very far from a satisfactory understanding of the matter.

The aim of the present volume, Bulletin No. 30, is to present information concerning the annual loss of life in the United States due to this cause, and to reiterate certain established truths concerning dangerous exposures. For the years 1899 and 1900 a number of clippings, amounting to nearly 30,000, were used in determining losses and casualties due to lightning. It was found that as many as fifty clippings would refer to the same event. The labor of checking these clippings was considerable, and at the close of 1900 this method was very properly discontinued. The data in possession of the Weather Bureau now extend over a period of eleven years, from 1890 to the close of 1900. During the year 1900 seven hundred and thirteen persons were killed by lightning, and nine hundred and seventy-three persons severely injured. It is rather startling to realize that in a single year more than sixteen hundred lives are thus jeopardized. Of this number more than five hundred were struck while "in the open," and it is noticeable that nearly three hundred of these were killed; one hundred and fifty-eight persons were killed in houses, and three hundred and twenty-seven injured. A very significant statement is that "men like animals are killed, not singly, but in bunches when they huddle together."

The interesting statement is made that the greatest fatality of a single stroke occurred at Chicago, where eleven persons huddled together in a zinc-lined shanty, under a North Shore pier, met instant death by a single bolt. We trust that the full particulars of this accident are available, since some may think that the accident contradicts Faraday's famous experience in the

[1] By Professor A. Henry, Weather Bureau Bulletin No. 30.

Digitized by Google

metallic cage, and is also not in accord with the well recognized principles of protection used in electrometers and cable devices. We hope that in future editions of the bulletin Professor Henry will give us the fullest details as to this accident.[1]

There appear to be three regions of marked thunderstorm frequency, one in the southeast with its crest over Florida, one in the middle west, and one in the Middle Missouri Valley.

Professor Henry calls attention to the rather surprisingly large number of deaths by lightning in the middle Rocky Mountain region. Considering the sparsity of population, the rate is very high for the States of Montana, Colorado, and Wyoming.

A well thought-out and carefully-written analogy of the earth, air, and cloud condenser to a vast Leyden jar is given by the author, and it would be well if text books on meteorology, in the chapters generally devoted to atmospheric electricity, would make use of these three or four pages. Two very interesting maps are given in the bulletin, one of July 8, 1898, showing thunderstorms southwest of an area of low pressure; and the other, June 25, 1901, showing thunderstorms in an area of high pressure.

A. MCADIE.

[1] I find, on further investigation, that the structure referred to in Bulletin No. 30, as "a zinc-lined shanty" would have been better described by the appellation "zinc-*covered* shanty." It did not resemble in any way the metallic cage used by Faraday, and hence the accident does not throw any doubts upon his experiments.

An account of the catastrophe which appeared in the Chicago *Tribune*, under date of July 2, 1901, is given below. The pier referred to was simply a double row of piles driven into the earth, the interstices being filled with loose rock. There was no covering or floor on the piles except at the end where the accident occurred. Here some loose pieces of abandoned zinc had been thrown over the top of the piles as a shelter against the rain, and it was under this rude shelter that the accident occurred.

Weather Bureau, April 16, 1902. A. J. HENRY.

Extract from Chicago *Tribune*, July 2, 1901.

Eleven boys and one man, huddled at the Robbins Pier, near the foot of Montrose Boulevard, Lake View, were struck by a single bolt of lightning. The man and ten of the boys were instantly killed. All had been fishing at the pier and had retreated under a zinc-covered shed to escape the heavy rain.

The adult victim was forty-five years of age, while the others ranged in age between eleven and twenty-three. The only person to escape was taken from under the heap of bodies with his legs and back paralyzed by the shock.

That portion of the pier covered by the rude zinc roof was so small that the victims had been crowded together in a heap. They were pressed so close together that all had been killed by the one thunderbolt, as by a current in an electrocution. The faces of the dead were blackened almost beyond recognition, and the bodies were scarred and seared from head to foot.

The catastrophe is unprecedented, so far as recorded lightning fatalities are concerned. In Chicago there has been but one instance when more than one or two persons were killed by a single bolt. The exception was the accident at the World's Fair, where four persons were killed by a lightning stroke at the Grant Monument in Lincoln Park.

In Haydn's Book of Dates the largest fatality recorded is from a bolt which killed nine persons. That was in 1819 at a church in the Alps.

Digitized by Google

CONTRIBUTION TO THE KNOWLEDGE OF ATMOSPHERIC ELECTRICITY.

In a paper, under the above title, read before the Royal Academy of Science of Vienna, on February 21, 1901, Prof. F. Exner discusses the daily period in the variations of atmospheric electricity, and, by comparing the records of observations made at a number of widely separated stations, shows a very intimate relation between those variations and the variations in the number of ultra-violet solar rays which reach the earth; and he further shows that the air strata which cause the variations are located very near the earth's surface.

He was led to suspect this relation from observations made by himself at Luxor, Upper Egypt, and in order to study it he compared actinometric and atmospheric electrical measurements made at Batavia, Ceylon, Delhi, Luxor, Wolfenbüttel, St. Gilgen and Spitzbergen.

For Batavia, Delhi, and Luxor the electric curves show a strong double daily period, with maxima about 8 A. M. and 8 P. M., local time, which are separated by a marked midday depression, and the actinometric curves show a sudden diminution in the number of solar rays about 11 A. M. and a sudden increase about 1 P. M. For Spitzbergen the curves show the same variations, but they are not so marked. For Ceylon and St. Gilgen the electrical curves show a single daily period, with a maximum running through the day-time hours and a minimum running through the hours of night-time, and the actinometric curves show a steady increase in the number of rays during the morning hours and a nearly symmetrical decrease during the afternoon hours. For Wolfenbüttel the curves change in character with the seasons and show a double daily period during the summer and a single period during the winter months.

From the above facts it is assumed as very probable that there is an intimate relation between the two phenomena; and it is concluded that the double period is due to the formation of an absorbing air stratum which not only absorbs the ultra-violet solar rays, but also causes negative electrification in the atmosphere; and since the double daily period occurs only in barren regions, as at Delhi and Luxor, and the single period in damp regions, or in regions covered with vegetation, as at Ceylon or St. Gilgen, it is further concluded that the absorbing properties of the air stratum are due to the presence of exceedingly fine dust particles which are carried upward by convection currents set up during the hours of strong insolation of the earth's surface.

The latter conclusion is confirmed by the fact that at some stations, as at Wolfenbüttel, the double daily period occurs during summer, when the air is laden with dust particles, and the single period during winter, when the air is pure.

At Luxor it was found that, on the level, the daily range in air potentials was from 50 to 300 volts, while on the summit of a hill, near by, and at an elevation of about 150 meters, the extremes were 110 and 160 volts. This shows that the air strata within 150 meters above a level surface contribute the greatest part of the cause of the daily period. This is also shown by observations made on the Eiffel Tower; the potential values at the top of the tower show a single daily period, while on the ground, at the foot of the tower, they show a double period.

Digitized by Google

Prof. Exner sums his conclusions as follows:

1. The normal daily potential curve shows a single period.

2. The double daily period observed at many places is due to a disturbance of the normal period, causing a midday depression in potential values.

3. This depression is observed, chiefly, in dry localities (or during summer), and appears to be the result of the formation, about midday, of a negatively electrified stratum over the place of observation.

4. This stratum also shows itself by a strong absorption of the ultra-violet solar rays.

5. The elevation of this stratum probably does not exceed one hundred meters.

L. G. SCHULTZ.

THE INFLUENCE OF THE ELECTRICAL STATE OF THE ATMOSPHERE ON THE BAROMETER.

In an article running through the numbers of "Climat" for September 15 and October 15, 1901, Mr. A. Zheltukhin, of the Russian Central Physical Observatory, St. Petersburg, advances the theory that barometric fluctuations, which occur during thunderstorms, are due to the electrical state of the atmosphere.

The theory is founded upon the assumption that the atmosphere is:

I. An electrostatic field of force:

II. A medium through which Hertzian waves are propagated;

III. A Newtonian field of force.

As to the electrostatical part of the theory Prof. Mascart's deductions are followed:—that air molecules absorb electrical energy from the sun; that as atmospheric density decreases with elevation above the surface, at high altitudes there are fewer molecules to a given volume of air and there is, therefore, less electrical energy absorbed than at the earth's surface, so that air potentials vary as the density, being highest near the ground; furthermore that, in cloudy weather, the clouds intercept the greater part of the solar electrical energy, and thereby cause abnormal potentials at the surface.

In his famous experiments Hertz showed that electrical waves are propagated through the atmosphere in the same manner as light waves, and that they likewise show the phenomena of interference, reflection, refraction, polarization, and variation of intensity. By means of a simple device Larroque was enabled to detect Hertzian waves, in France, which were caused by electrical discharges during a thunderstorm in the Grampian Hills of Scotland, and, on another occasion, during a storm in the Maritime Alps; in each instance the sky was clear at the place of observation and the storm was several hundred kilometers away.

It is an established law that at any given point in the earth's atmosphere the tension of the Newtonian field is a constant quantity, not changing with the time; hence a given volume of air of constant mass, with its center of gravity at a given point, will always have the same weight at that point. As each stratum of air must support the weight of all superincumbent strata, the height of a column of air may be measured by means of the barometer. Now if it be assumed that the Newtonian field acts alone in producing barometric variations it must follow that such variations indicate a mechanical transfer

Digitized by Google

of air masses to or from the column under consideration. But it has been found that barometric fluctuations, caused by thunderstorms, occur simultaneously at places from 300 to 600 kilometers apart—far enough to preclude the idea that they are the result of only mechanical processes at work in the air—hence they must be due to other forces.

As the barometer measures the resultant of all forces at work in the field of the atmosphere, and as the effect of the Newtonian field is constant, it is concluded that barometric variations are due to the electromagnetic changes which go on constantly within the field. L. G. SCHULTZ.

BÖRGEN'S INVESTIGATION OF THE EFFECT OF THE MAGNETIC MOMENT AND OF DISTANCE UPON THE POL-DISTANCE OF MAGNETS.

The above research is a continuation of the author's work published in 1891 in the *Annalen der Hydrographie*, where he sets forth a new method for determining the "pol-distance" of a magnet. The article is very elaborate, giving all the details as to the various theoretical and practical corrections necessary for a strictly accurate determination of this important correction factor. Six quarto pages of tables are appended for the calculation of various correction factors in case of continued measurements with the same apparatus.

The new method of observing for this determination of pol-distance and horizontal intensity consists in placing the deflecting magnet east and west of the deflected needle, as in the Gauss and Lamont methods, but unlike these, where the deflection of the needle is observed for different distances of the magnet, in Börgen's method the "deflecting magnet" is rotated upon a vertical axis through its center of figure, perpendicular to its length, until the "needle" is brought back to its zero position. The quantities observed are the three distances, being the sides of the triangle, the angles of which are at the center of the needle, the center of the magnet and the intersection of the axis of the needle with the axis of the magnet, north or south of the needle.

The results obtained with a bar magnet 12.36 cm. long, 0.45 cm. wide, and 0.22 cm. thick; i. e., a long, thin magnet, the moment of which was changed by "stroking," are given below:

Sequence of Determinations	Mag. Moment	Pol-Distance	Prob. Error	Ratio of Pol-Dist. to Length
Third,	191 C. G. S.	10.1271	±0.0031	0.819
First,	386 " " "	10.0248	0.0045	0.811
Second,	579 " " "	9.9461	0.0060	0.805
Fourth,	667 " " "	9.9429	0.0049	0.804

The conclusions are drawn:

1. The pol-distance of a magnet decreases with increasing magnetization.

2. In strong magnets the ratio of pol-distance to the length of the bar may be put at 0.805.

This is at seeming variance with the work of Dr. Eschenhagen in 1886, who found no variation as above; but Börgen justly remarks that Eschenhagen used magnetizations all above 493 C. G. S., and had doubtless reached the constant value for "*strong* magnets," as above indicated.

Digitized by Google

Certain observations were made to determine whether the distance apart of the needle and magnet effected the pol-distance. The results were as follows:

Distance apart of Centers	Pol-Distance	Probable Error	Ratio
15.90 cm.	9.9429	±0.0049	0.804
21.86 "	9.9961	0.0081	0.809
27.89 "	10.0100	0.0121	0.809

The conclusion is drawn that there is a slight but definite effect due to distance.

In this connection it must be borne in mind that the magnetometer needle consists of three laminæ, 1.65 x 0.2 x 0.02 cm. each, and in none of the three cases were the two magnets 30 cm. apart. It is entirely possible that this rather formidable "needle" might slightly affect the distribution of magnetism in the deflecting bar. It must not be forgotten in either this case or the other that the bar magnet in the different cases stood at different angles to the Earth's field.

Final conclusions are:

1. The pol-distance of a magnet depends upon its magnetization, decreasing as the magnet becomes stronger, but approaches a limit asymptotically.

2. There is also a small effect due to the distance apart of needle and magnet, both distances increasing together.

3. The Kohlrausch-Hallock value of 5/6 is too large, and should be reduced from 0.833 to 0.805 for strong, and 0.815 for weak magnets. This is subject to revision when other magnets are investigated.

4. The above method of determining this ratio is much better than the Lamont method.

In spite of the fact that only one magnet was investigated, and it was magnetized in a rather irregular and inefficient way, and a very complex set of symbols and formulæ were employed, nevertheless a real contribution has been made to our knowledge and methods, which will be of great value to students in terrestrial magnetism. W. HALLOCK.

COLUMBIA UNIVERSITY.

DIRECTION OF MAGNETIZATION IN CLAY BEDS BAKED BY LAVA FLOWS, BY B. BRUNHES AND P. DAVID.[1]

When clay is baked it assumes in the process of cooling a very stable magnetization in the direction of the terrestrial magnetic field. This fact is the basis of Folgheraiter's method of determining magnetic dip in past ages by the residual magnetization of pottery; but the conclusions are not absolute, since the exact orientation of the pottery during baking must be known (and also the locality in which the pottery was made).

The authors have made an examination of the declination and dip of a partially transformed clay bed in a volcanic region near Clermont. In the environs of Clermont are found horizontal beds, dating from the upper pliocene and early quaternary, upon which there was superposed a lava bed of great regularity. The heat to which the clay was thus subjected baked it to

[1] Sous la direction d'aimantation dans des couches d'argile transformée en brique par des coulées de lave. Comtes Rendees, July 15, 1901, pp. 155-157.

Digitized by Google

a depth of ⅔ meter. The circumstances preclude the possibility of any change in orientation. Specimens (8 cm. cubes) from a given locality show a great uniformity in magnetization, although the intensity of magnetization varies between 0.0018 to 0.00045 c. g. s. units.

The mean difference between the declination as reduced from the magnetization of the clay bed and the present local declination is 7°—9° 30′, the former being east of the latter, and an inclination between 56° 30′ and 58° 30′.

Clay subjected to lava flowing from other volcanoes gave different results. This might enable a conclusion to be reached as to whether two eruptions in the same region were or were not contemporaneous.

The magnetization indicates that there can not have been any reversal of the Earth's polarity, as suggested by M. Folgheraiter from his observations on the magnetization of pottery. F. A. WOLFF, JR.

MAGNETIC WORK IN THE AZORES.[1]

Captain Chaves gives a brief history of the different determinations of the magnetic elements, recalling the fact that Columbus crossed the agonic Sept. 13, 1492, three degrees west of the Isle of Flores, and collects all the results in a table, which he briefly discusses, pointing out the fact that there are large local influences at work all over the group of islands. For a brief statement of the important magnetic work contemplated, see T. M., Vol. III, p. 119. J. W. MILLER.

DISTRIBUTION OF MAGNETISM AS AFFECTED BY INDUCED CURRENTS IN AN IRON CYLINDER WHEN ROTATED IN A MAGNETIC FIELD.[2]

Object:—The effect of induced currents on the distribution of magnetism in an iron cylinder when rotated about its longitudinal axis in a magnetic field normal to this axis is of interest because the results have a wider application than to the cylinder used. Similar phenomena are factors in determining the design of a certain class of induction motors having solid iron armatures, and are also of interest in connection with the theory of the secular variation of terrestrial magnetism.

Apparatus and Method:—The work was done with a mild steel cylinder of some 25 cms. diameter and equal length. The value of the induction over elements of the cross-section of the cylinder was secured by means of coils threaded through holes drilled in a plane containing the axis of rotation, so as to surround six different areas, three of which were about 25 sq. cms., and three 50 sq. cms. Another coil was wound on the outside of the cylinder

[1] CHAVES. F. A.—Rapport sur l'establissment projeté du service météorologique international des Açore. Monaco, 1900, 22 x 27 cm., 66 + 2 pp., 2 plates (barograms) 4 views and 2 maps.

View I—Port of Ponta Delgada, S. Miguel.

View II—Mount Pico seen from Horta; Observatory of Horta.

View III—General view of Horta, Fayal.

View IV—Faja de Porta à Flores.

Map I—Azores; Map II—Storm tracks in the Atlantic Ocean.

[2] By Ernest Wilson, Professor of Electrical Engineering, King's College, London. Read before Royal Society, London, January 30, 1902.

Digitized by Google

in the plane of the inside coils. The cylinder was rotated between the pole pieces of a bi-polar Siemen's field-magnet, the period of rotation varying from 360 seconds to 22.5 seconds. A D'Arsonval galvanometer was in circuit with each coil, and readings were made simultaneously in all. By integration of curves plotted for each coil between e. m. f. and time, the maximum intensity of induction at each half period for different points along radius of the cylinder was secured.

I. RADIAL VARIATION OF INTENSITY OF INDUCTION:—The effect of a change in the frequency of rotation on the radial distribution of induction is such that at higher frequencies intermediate values of the external magnetizing force play a more important rôle, and the center of the cylinder is more shielded and the range of shielding inside the cylinder is greater than for lower frequencies. The crowding of magnetism to the surface at higher speeds was very well shown in that the values of maximum induction at the surface were 17,000 and 7,000 respectively for periods of 22.5 seconds, and 360 seconds, while the average throughout the whole cylinder was only 6850 in the first case, and as much as 6970 in the second.

II. ALTERNATING MAGNETIZING FORCE:—A slightly larger cylinder of mild steel furnished with coils similar to those of first cylinder was rotated about its longitudinal axis in the field of an alternating magnetizing force parallel to the axis of rotation. The radial variation of average induction was very similar to that secured in the cylinder rotated in a steady field; but the shielding effect of the alternating field is greater than that of rotating field for corresponding values of frequency and of surface induction for the same cylinder of a diameter equal to its length.

III. PHASE DISPLACEMENT OF E. M. F.:—The phase-displacements of e. m. f. in the other three coils with respect to e. m. f. in the coil nearest the surface of the cylinder were more marked for the stationary cylinder in the alternating field than for the rotating cylinder in the steady field. The region of greatest sensitiveness of the induction at the center for changes in the induction at the surface is also the region of maximum phase-displacement. The maximum phase-displacement occurs at lower surface induction the lower the frequency, for both cylinders. For very high induction the e. m. f. curves for all coils are practically in phase.

IV. LONGITUDINAL VARIATIONS:—The effects of the induced currents penetrate from the ends of the cylinder in much the same way as radially, though the diminution of intensity is not so rapid, nor the phase-displacements so marked.

On the principle that if the ratio of the homologous dimensions of two similar cylinders be n, in order to induce the same e. m. f. at similar points, the speed of rotation in the same field must vary inversely as n^2, the author shows that if .00000001 cm. be the order of magnitude of the smallest mass of iron which retains the characteristic properties, such a mass would have to rotate 7×10^{14} times per second in order to suffer effects similar to those observed in these experiments at periods of 90 seconds.

Some applications of the results are also made to the design of dynamo-electric machines and to the phenomena of terrestrial magnetism, but we confine ourselves here to the results.

Digitized by Google

As Dr. Bauer has pointed out,[1] Hertz, in 1880, solved the problem of the induction of electric currents in rotating spheres, taking into account self-induction. He also examined, both theoretically and experimentally, the case in which the sphere assumed magnetic polarity. Barlow, in a paper before the Royal Society, in 1825, gave some experimental results on "the temporary magnetic effect induced in iron bodies by rotation," showing that when any iron body is rotated about an axis not coinciding with its magnetic axis, a temporary derangement in its distribution of magnetism occurs which is equivalent to a new axis of polarization normal to the plane passing through its axes of rotation and polarization.

Phenomena somewhat analagous to the effects secured by Professor Wilson with the alternating field were studied by M. Ch. Maurain in 1898.[2] He investigated the shielding effect (i. e., the decrease in the field-strength as you proceed into the body of a conductor) due to the currents induced by an external alternating field, in rings and cylinders of both non-magnetic and magnetic conductors. In the case of iron he showed that, with a given frequency, the shielding at first increased with increasing intensity of external field, passed through a maximum, and then decreased more slowly. This maximum shielding was secured at a considerably higher intensity than that which corresponded to the maximum permeability of the iron. With a constant external field-strength and increasing frequency the shielding increased continuously, but not as rapidly as with non-magnetic screens, such as copper. In the second part he studied the variation with frequency of the energy dissipated each period in a magnetic ring subjected to an alternating field, and showed that for an unlaminated ring the energy-loss decreased as the frequency increased, the mode of variation being explicable by the action of induced currents; for laminated rings, in which the energy-loss is due, very sensibly, to the magnetization alone, it is independent of the frequency. A study of the variations of maximum flux of induction led to the same results. This maximum always lags behind that of the external current, even for the most completely laminated rings, which shows that there is an effective lag of magnetization behind the exciting field. C. K. EDMUNDS.

JOHNS HOPKINS UNIVERSITY.

MAGNETIC OBSERVATIONS MADE AT BUCHAREST DURING THE YEAR 1899.[3]

This paper gives the results of the absolute and differential determinations of the magnetic elements made at the magnetic Observatory at Bucharest in 1899, together with brief descriptions of the methods and instruments employed. The year 1899 was the first in which the variation instruments of this Observatory were in operation during the entire year.

The absolute observations were made at periods from five to ten days

[1] T. M., p. 24, Vol. VI, No. 1.

[2] THÉSE. "Recherches sur les Écrans Électromagnetiques et l'Influence de la Frequency sur l'Energy Dissipée dans l'Amiantation." M. Ch. Maurain, Paris, 1898.

[3] I. St. Murat: Analele Institutului Meteorologic al României, Tom. XV, Partea 2, Anul 1899.

Digitized by Google

apart with theodolite-magnetometer Chasselon No. 9 and dip circle Chasselon No. 14. The results for declination, horizontal intensity, vertical intensity, and inclination are given in Tables I, II, III, and IV.

The variation instruments consist of two complete sets of the Mascart pattern—one an eye-reading, the other a self-registering set. Each set comprises a declinometer, a bifilar, and a vertical force balance. The instruments are mounted in such a way that the three eye-reading telescopes rest upon a single pier, and the three photographic traces appear on the same sheet.

Table V gives the values of the declination and horizontal and vertical intensities for every six hours each day in the year, together with the daily means of all the hourly values.

Table VI gives the number of disturbances occurring each month in declination and horizontal intensity. For declination the maximum is 173 in May, and the minimum 13 in December. For horizontal intensity, maximum 307 in both August and September, minimum 142 in December.

Table VII gives the hourly distribution of the disturbed values. For declination the maximum is 187 at 13 h, and the minimum 9 at 2 h. For horizontal intensity, maximum 176 at 10 h, minimum 85 at 3 h.

Tables VIII and IX give for the declination and horizontal intensity the difference between the mean value for the same hour throughout the month and the monthly mean.

From the values of the elements as determined on January 1, 1899, and again on January 1, 1900, the secular variation is found as follows:

	Jan. 1, 1899.	Jan. 1, 1900.	Annual variation.
Declination, ...	4° 22.′8	4° 19.′5	—3.′3
Inclination, ...	58 48. 4	58 47. 6	—0. 8
Hor. intens., ...	23309γ	23319γ	+10γ
Vert. "	38492	38496	+ 4
Total "	45003	45008	+ 5

WM. F. WALLIS.

MAGNETIC OBSERVATIONS AND THE AURORA BOREALIS IN NORWAY.[1]

The first half of this volume contains a discussion of the results obtained on the expedition sent out partly at the expense of the Norwegian Government in the winter of 1899–1900. The station occupied was near Bossekop, on the Mountain of Haldde, in the north of Norway, the work being conducted by Professor Birkeland, with three assistants.

It should be stated at the start that the observations are discussed in the light of Birkeland's theory, which may be briefly summed up as follows: The Sun emits cathode rays, or possibly some other similar form of radiation, which, when passing near the Earth, are sucked into its magnetic field and tend to run along lines of magnetic force. These streams of rays give rise

[1] Expédition Norvégienne de 1899-1900 pour l'etude des aurores boréales. Resultats des recherches magnétiques par Kr. Birkeland. Christiania, 1901. 8vo, 80 pages and 12 plates. Résultats des Recherches Magnétiques faités etc. Archives Sc. Phys. et Nat. Geneve, Dec. 1901.

Digitized by Google

to electric currents that circulate in the upper regions of the atmosphere, starting in general in the region of the poles, where they are well concentrated and in condition to cause the optical phenomenon known as the aurora. The atmospheric current is situated about 100 km. above the surface of the Earth; moving first toward the south, it divides, one part moving east and the other west, finally returning to the pole once more. It is not affected by the diurnal rotation of the Earth, but is subject to certain sudden changes at times of disturbances. The perturbations in the Earth's magnetism are due to this current, which during great disturbances may attain a total intensity of 400,000 ampères.

The instrumental equipment consisted of an Eschenhagen Magnetograph for recording variations in declination and horizontal intensity, capable of being run when desired at high speed, in which case one hour was represented by an abscissa 24 cm. in length; a vertical intensity magnetograph was also employed. An Elster and Geitel atmospheric electricity variometer was used, with a plate coated with radium as collector; owing to difficulties in the operation of the instrument, no certain connection between electrical and magnetic variations was established.

For certain selected disturbances the magnetograph records from the observatories at Pawlowsk, Copenhagen, Potsdam, Greenwich, and Toronto are discussed in connection with the Haldde observations. An agreement had also been made with the Potsdam Observatory, whereby the instruments in both places were run simultaneously at high speed during certain term hours. The chronometers at Haldde were checked twice a week by means of telegraphic time-signals received from Christiania.

From the comparisons of Haldde and Potsdam high-speed records it is apparent that the time of occurrence of small disturbances is practically simultaneous at the two stations. The times of 44 disturbances were computed from the declination magnetograms, though an accuracy of only 10 seconds is claimed for the measurements. The mean apparent difference between the two stations was only 1 second. In the case of horizontal intensity the identification of the same disturbance at both stations was more uncertain, and the mean difference was 7 seconds, still, however, within the limits of error.

The question of the period of Eschenhagen's "Elementarwellen"[2] is next taken up. An examination of a large number of cases from Potsdam shows a preponderance of waves of periods about 30 seconds, though all periods from 8 to 125 seconds occur. The waves of shorter period, including those of 30 seconds, are not found so often in the Haldde records.

Birkeland considers the large magnetic disturbances of long duration, like the small waves, to be due to the atmospheric electrical currents. In pages 13–36 we have a discussion of the results bearing on this point, especially the records from all the observatories for six marked disturbances. The disturbing forces are resolved into components parallel and perpendicular to the magnetic meridian, and their directions and times of maximum intensity compared for the different stations. The location and intensity of the disturbing atmospheric currents can then be estimated. The currents affecting the horizontal magnetic components seem to be chiefly those passing

[2] *Cf.* Vol. II, 105.

Digitized by Google

directly above the point in question, while the vertical intensity is influenced mostly by currents passing at one side or the other. In passing from an eastern to a western station, we find that the currents seem to have rotated in the direction of the hands of a watch. These and other interesting deductions are drawn from the original curves and from the vector diagrams.

The most important conclusion, for the present stage of the science, is that the maxima of large disturbances do not occur at the same moment of absolute time at all stations, but that they come earlier at eastern than at western stations. This point deserves further and more extended observations; for, if true, it must be very significant in its bearing on the theory of terrestrial magnetic phenomena. The author's attempt to reconcile the evidence with the supposition that the disturbances are due to electrical currents (p. 14) does not seem to us quite satisfactory.

The second half of the volume consists chiefly of the discussion of certain experiments with vacuum tubes. There is always a strong fascination in the attempt to reproduce complicated natural phenomena on the scale of laboratory experiments. The more gigantic the original phenomenon, and the more striking the experimental representation of it, the stronger grows the fascination, and the inclination to draw sweeping conclusions increases correspondingly. The analogy between the aurora borealis and the cathode rays has been noted by many observers, but none have carried the comparison so far and with such ingenuity and plausibility as Professor Birkeland. Lack of space prevents our giving a full description of the experiments. They comprise, for example, an investigation of the fluorescence on the surface of an iron globe representing the Earth when under the influence of the cathode rays. Other experiments were made with vacuum tubes of various forms, in which cathode rays were generated and made to pass through a magnetic field. The common auroral types were reproduced in this manner, as shown by a number of excellent photographs. These different types are taken up at some length, and by a consideration of their laboratory analogies the attempt is made to describe the probable origin of the phenomena. The effect of the Moon on the aurora and on the Earth's magnetism is explained on the ground that the cathode rays from the Sun are deflected when they pass near the Moon on their way to the Earth.

The cathode ray hypothesis is also used to explain certain forms of cloud condensation, and especially the formation of clouds at times of auroral displays. The much-discussed cirrus and cirro-stratus clouds are attributed to the same cause.

Professor Birkeland has given us some very suggestive reading throughout this discussion. He has handled his data with great skill, and so far seems to have a plausible explanation for most of the phenomena that have come under his observation. But the field is a vast one, and no hypothesis can be accepted until it has been tested repeatedly under all possible conditions. *Direct* evidence we may never have; hence it behooves us all the more to turn our attention to the amassing of observations in order to make our indirect evidence as convincing as possible. It is a bold hypothesis that Professor Birkeland has propounded: it is to be hoped that some light will be thrown on its validity when the international simultaneous observations of the present year are discussed and correlated. W. G. CADY.

Digitized by Google

WATSON'S DETERMINATION OF THE VALUE OF THE EARTH'S MAGNETIC FIELD IN INTERNATIONAL UNITS AND A COMPARISON OF THE RESULTS WITH THE VALUE GIVEN BY THE KEW OBSERVATORY STANDARD INSTRUMENTS.[1]

[Abstract.]

A comparison of the readings given by the magnetometers used for measuring the horizontal component of the Earth's magnetic field at the various observatories in Great Britain having shown the existence of very marked discrepancies, although the instruments employed are all of the same type, it seemed of interest to employ some entirely different method for the measurement of H, and to compare the results with those given by the unifilar magnetometers. This paper contains a description of such a measurement. The method employed consists in passing a known current through a coil of known dimensions and comparing, by means of a suspended magnetic needle, the field at the center of the coil, due to the passage of the current, with the horizontal component of the Earth's field. The current employed has been measured in two ways: (1) By the deposition of silver in a voltameter, and (2) by a potentiometer method, in which the difference of potential at the terminals of a known resistance is balanced against the E. M. F. of a standard Clark or cadmium cell.

As a result, it has been found that, taking the electro-chemical equivalent of silver as 0.001118, the value of H as determined by this galvanometer method is 0.00006 C. G. S. unit lower than the value given by the Kew Observatory standard instrument. If, as seems probable, the true value of the electro-chemical equivalent of silver is 0.0011183, then this difference is increased to 0.00014 C. G. S. unit.[2]

MAGNETIC OBSERVATIONS IN SPITZBERGEN IN 1898.[3]

BY V. CARLHEIM-GYLLENSKÖLD.

The following magnetic results were obtained in connection with the geodetic work of the measurement of an arc of a meridian as opportunity presented itself. Two old magnetometers of the Lamont pattern, a Dover dip

[1] Phil. Trans. R. S., series A, vol. 198, pp. 431-462. London, 1902. The Abstract is taken from the Proc. R. S. 451, Nov. 8, 1901.

[2] Regarding above, the Editor has received the following note from Prof. Palazzo: "When I was at Kew, in the summer of 1898, on comparing the magnetic instruments belonging to the R. Italian Meteorological Office with those of the Kew Observatory, I also found that the value of H as given by the Italian unifilar magnetometer was precisely 0.00006 C. G. S. unit lower than that given by the normal English instrument.[4] It is not that I am inclined to attribute any great weight to this numerical coincidence, which might be more or less the result of change, but it has given me satisfaction to note that the value of H as given by my magnetometer and as obtained by Watson's improved galvanometer method is one and the same."

[3] Travaux de l'expédition suédoise au Spitzbergen 1898 pour la mesure d'un arc du méridien. No. 3. Détermination des éléments magnétiques. Öfversigt af Kongl. Vetensk. Akad. Förhandlingar 1899. No. 9. Stockholm. 901-920.

[4] Rend. Acc. Lincei, Vol. VIII, 1° Tem., p. 386, 443.

298712

Digitized by Google

circle, a Hechelmann magnetometer and dip circle combined, and a Pistor and Martins' compass, constituted the magnetic outfit. The true meridian was determined from sun observations.

The dips were in general determined without reversal of polarity of needles; however, observations for determination of balance error were made at Stockholm before and after the work, and at two stations in Spitzbergen, viz., at Bellsound and Treurenberg Bay, and the proper corrections as deduced from these observations applied to the observed dips. The Hechelmann dip circle agreed well with the Dover circle at Stockholm; but comparative observations between the circles made at Bellsound and Treurenberg Bay, resulted in showing that the Hechelmann circle gave results 0°.8 to 1°.2 too high on the Dover circle!

The horizontal intensity was frequently determined from oscillations alone, using interpolated values of the magnetic moment, as deduced from the absolute observations at other stations.

RÉSUMÉ OF RESULTS.

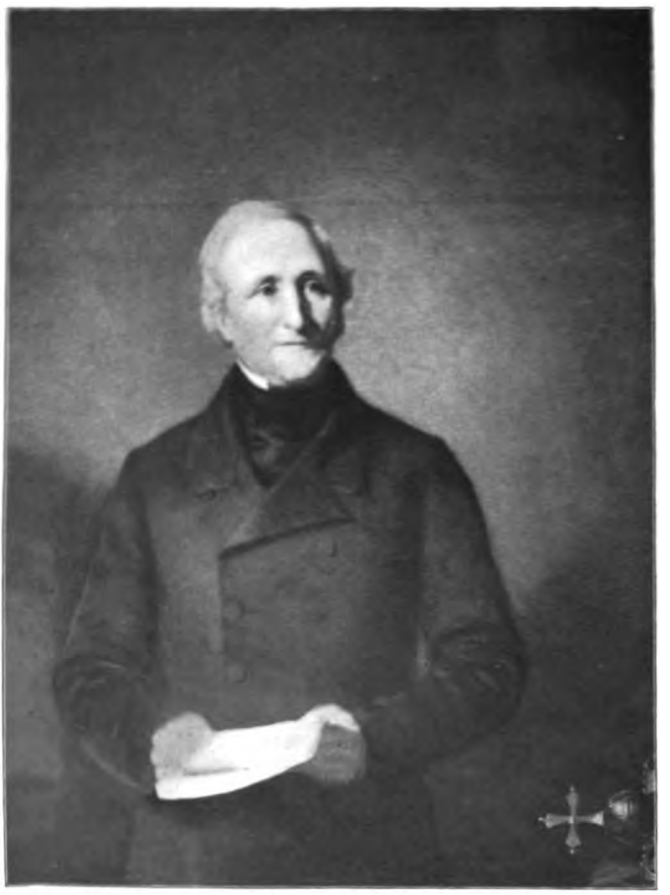
Station	Date 1898	Latitude	Longitude E. of Gr.	Magn'c Declination W.	Magn'c Inclination	Horizontal Intensity
		° ′	° ′	° ′	° ′	c. g. s.
Bel Sound, Baie de la Recherche, ...	June 20, 21	77 30	14 50	12 33	80 17	0.0914
Adventbaie, ...	" 24	78 15	15 32	11 11	80 22	0.0906
Skansbaie, ...	" 25	78 31	16 03	10 55	.....	0.0873
Ile danoise, ...	" 28	79 43	10 45	14 30	.....	.....
Hecla Cove, ...	July 1	79 55	17 00	.....	81 12	0.0816
Stora Ryssön, ...	" 24	79 59	18 14	....	81 14	0.0804
Montagne de Celsius, . .	" 28	80 00	18 51	8 45	81 20	0.0794
Cap Faushawe, ...	Aug. 1	79 37	18 14	.....	81 07	0.0849
Lommebaie, hâvre, . .	" 4	79 36	17 47	.....	80 59	0.0879
Montagne de Lovén, . .	" 4	79 23	18 43	.....	80 59	0.0859
Isle de Wahlberg, . . .	" 7	79 19	20 07	.....	.....	0.0847
Thumb Point, ...	" 9	79 04	20 43	6 51	.....	0 0774
Wijdebaie, Ostfiord, . .	" 17	78 55	16 17	8 52	80 43	0.0807
Cap Lee, ...	" 28	78 05	20 54	4 56*	80 27	0.0711
Iles d'Anderson, ...	Sep. 3	78 20	20 43	.....	80 28	0.0881

*Uncertain by 15′-30′ because of strong wind squalls.

Digitized by Google

FOUNDATIONS.

Digitized by Google



MAJOR-GENERAL SIR EDWARD SABINE.

[From the portrait in the Rooms of the Royal Society, Burlington House, London.]

Digitized by Google

Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME VII SEPTEMBER 1902 NUMBER 3

UEBER DIE METEOROLOGISCHE NATUR DER VARIATIONEN DES ERDMAGNETISMUS.

A. NIPPOLDT, POTSDAM.

Wenn man die Curven unserer Magnetographen betrachtet und von augenscheinlich gestörten Tagen absieht, so zeigt sich uns aufs deutlichste, dass wir es hier mit einem sehr gesetzmässigen Vorgange zu thun haben; dennoch wissen wir über die Quelle dieser Gesetzmässigkeit noch sehr wenig. Die von Schuster geschaffene und von Bezold so eingehend discutierte Theorie der täglichen Variationen, zeigt zwar, dass man ein System magnetischer Kräfte construieren kann, innerhalb dessen die Erde rotiert, und das die genannten Variationen erzeugen könnte, allein damit verlegt sich die Frage nur und lautet jetzt: Wodurch entsteht ein solches System?

Dass es ein rein magnetisches ist, ist unwahrscheinlich, denn die Atmosphäre enthält keine Bestandteile, die genügend magnetisierbar sind, und *sie* ist doch der Sitz dieser Kräfte. Zwar wäre ein cosmisches Feld denkbar, allein der Verlauf der Kraftlinien trägt doch einen unverkennbar irdischen Character. Daher muss man annehmen, dass das Feld electrischer Natur ist. Dann aber hängen dessen Ströme von der Leitfähigkeit der Luft ab und mithin unter anderem sehr wahrscheinlich von ihrem *meteorologischen Zustande.* Sie können ausserdem noch in Richtung und Intensität dadurch variieren, dass jene Ursachen variieren, welche die Ströme hervorgerufen haben. Diese Ursachen können ebenfalls terrestrischer Natur, aber auch cosmischen respective solaren Ursprunges sein, etwa in der Art der Theorien von *Birkeland*,[1] *Arrhenius*[2] und *Bigelow*,[3] die alle darin übereinstimmen, dass sie electrisierte

[1] BIRKELAND. Expéd. Norvégienne de 1899–1900. Vidensk. Skrift. Kristiania 1901.

[2] ARRHENIUS. Ueber die Ursache der Nordlichter. Phys. Zeitschr. II, 81–87, 97–105. 1901.

[3] BIGELOW. Magnetic Theory of the Solar Coronæ. Amer. Journ. of Science. 253–262. 1901.

Digitized by Google

Teilchen von der Sonne ausgehen und zum Teil die Erde treffen lassen. Es sei übrigens hier bemerkt, dass schon vor anderthalb Jahrhunderten *Mairan* in seinem Traité de l'aurore boréale, p. 455, Paris 1754, zur Erklärung der regelmässigen Variationen angenommen hat, dass von der Sonne feine Teilchen ausströmen, die die magnetische Nadel beeinflussen.

Es sind schon sehr viele Forscher, namentlich um den Anfang des vorigen Jahrhunderts, dazu gekommen, eine meteorologische Natur der erdmagnetischen Variationen anzunehmen, respektive einen solchen Einfluss in ihnen zu vermuten, worunter *Faraday's* Hypothesen am bekanntesten geworden sind. Fast jedes meteorologische Element wurde daraufhin schon untersucht. Alle diese Arbeiten gehen von der Vermutung aus, es bestünde eine Verbindung, sagen wir mit der Windrichtung, dem Luftdrucke, der Feuchtigkeit u. s. w. und vergleichen die betreffenden meteorologischen Beobachtungsreihen mit den magnetischen, um ihre Hypothese zu stützen.

Umgekehrt führte die harmonische Analyse der Declinations-Beobachtungen mehrere Stationen des internationalen Polar-Jahres 1882–83 den Verfasser dieser Zeilen unbeabsichtigt auf einen Zusammenhang der meteorologischen Variationen und Daten mit den magnetischen. Hierüber sei in Folgendem kurz berichtet.

Neu berechnet wurden die harmonischen Constituenten von *Pawlowsk* (*P*); ferner wurden folgende vorhandene Arbeiten herangezogen: *P. Huff*, der jährliche und tägliche Gang der erdmagnetischen Elemente zu *Tiflis* (*T*); *H. Meldau*, die tägliche und jährliche Periode etc. in *Wilhelmshaven* (*Wh*); *E. Gartke*, desgleichen in Süd-Georgien (*S. G.*); *G. Sack*, die tägliche, jährliche und elfjährige Periode etc. in *Greenwich*, alles Göttinger Dissertationen; *W. Kind*, Beitrag zur Bestimmung der täglichen Variation in *Fort Rae* (*F. R.*) (Programm d. Gymnasiums Stettin); *Fr. Schmidt*, der tägliche Gang etc. in *Wien* (*W*) (Jahrbuch für Meteorologie, Wien 1888); *P. Van der Stok*, Observations at *Batavia* (*B*) (Vol. XVI), und die mir auf freundlichste Weise handschriftlich zugesandten Werte des Coeffizienten für *Mauritius* (*M*), von Herrn *E. Engelenburg* berechnet. Nur die Werte letzterer beiden Orte beruhen auf mehrjährigen Mitteln, die übrigen umfassen, so weit sie verwandt sind, nur das Polarjahr 1882–83.

Die Beobachtungen wurden in der Form dargestellt:

$$\delta_x = u_0 + \sum_{n=1}^{4} u_n \sin (U_n + nx).$$

Digitized by Google

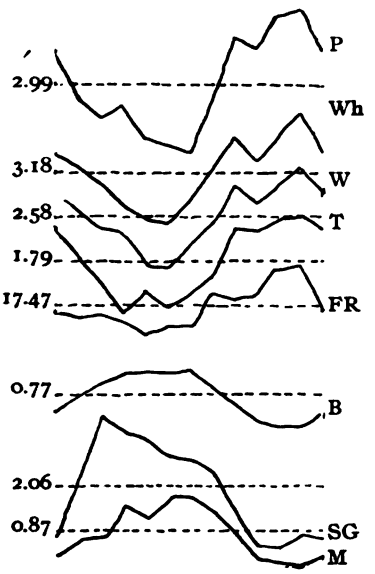
Yours truly, Zachary Taylor.

Digitized by Google

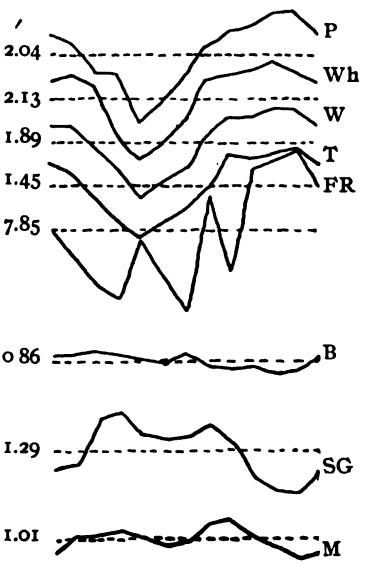
Digitized by Google

Dass die Glieder höherer Ordnung von keinem Einfluss auf das Gesetz des Verlaufes sind, konnte nachgewiesen werden. Ein Glied von der Form $u_n \sin (U_n + nx)$ heisse das Glied n^{ter} Ordnung, respective die Welle, w_n. u_n ist dann die (maximale) Amplitude, U_n die Phase n^{ter} Ordnung. Für jede Station erhält man für jeden Coeffizienten 12 Werte, falls das Material aus 12 Monatsreihen besteht, und kann also jährliche Verläufe der Coeffizienten bilden. Diese seien zunächst betrachtet.

u_1 (Figur 1). Jeder Millimeter in Höhe bedeutet 0.'18, nur bei *Fort Rae* ist 1 mm = 1'.8. Dafür, dass die meisten Curven nur auf einem Jahre Beobachtung beruhen, sind sie ausserordentlich ähnlich; auf der nördlichen Halb-Kugel tritt das Maximum um den Juli ein, auf der südlichen ist dies die Gegend des Minimum; hier ist eine halbe Phase-Verschiebung. Auch das andere Extrem zeigt diese Verhältnisse. Ausserdem ist der ganze jährliche Verlauf einfach. Beidesmal haben wir im Sommer das Maximum, im Winter das Minimum, also einen Einfluss der Jahreszeiten. Verschiebt man die Curven der Süd-Hemisphäre um 6 Monate und spiegelt sie am Mittelwert, so kommen Curven vom selben Character heraus, als die der Nordhalbkugel, obwohl die meteorologischen Zustände beider so sehr verschieden sind.



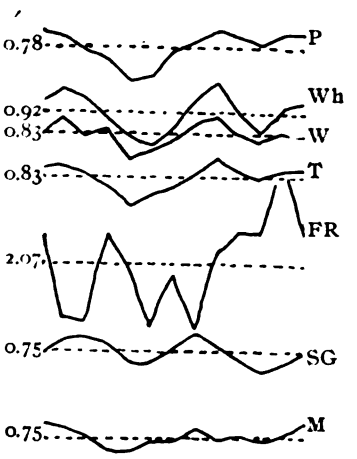
FIGUR 1. (u_1)



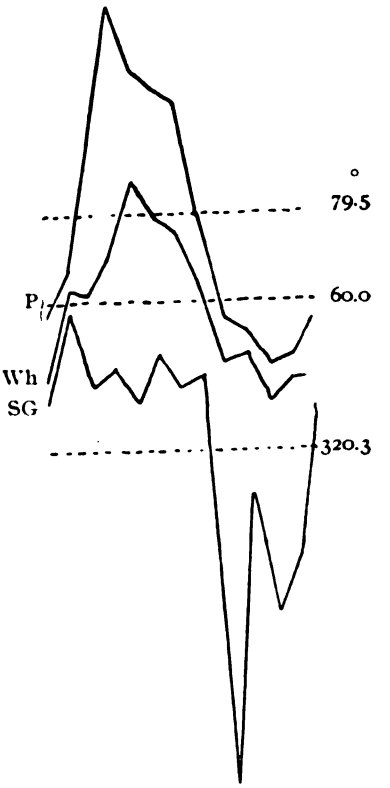
FIGUR 2. (u_2)

Digitized by Google

u_2 (Figur 2). 1 mm = o'.18. Hier ist ein ganz anderes Bild, als bei u_1, indem je die nördlichen Stationen unter sich übereinstimmen, und wieder die südlichen unter sich; letztere sind aber zweifach periodisch, erstere nur einfach. Die nördlichen sind zudem stärker variabel. Hier müssen also 1. andere Einflüsse vorliegen als bei u, und 2. solche, die auf der Nordhalb-Kugel stärker variieren.



FIGUR 3. (u_2)



FIGUR 4. (U_1)

u_3 (Figur 3). 1 mm = o'.18. Jetzt sind die Curven beider Halb-Kugeln zweifachperiodisch, auf der südlichen etwas regelmässiger. Die Doppelperiode sagt nichts über eine eventuelle Phasen-Verschiebung von einem halben Jahre aus. Daher ist aus den u_3 vorerst nur herauszulesen, dass sie Einflüssen zuzuschreiben, die auf der Nordhälfte der Erde stärker sind.

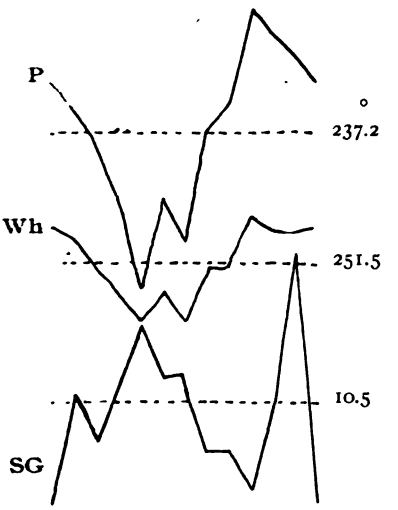
Digitized by Google

Bei u_4 scheint jede Gesetzmässigkeit zu verschwinden.

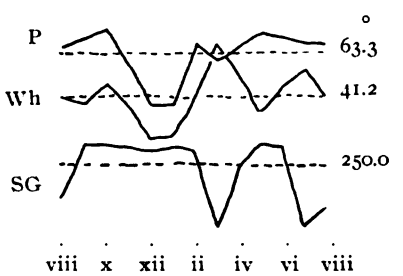
Wenden wir uns den *Angulär-Constanten* U_n zu, so sei zunächst bemerkt, dass der Raum-Ersparnis wegen nur die Curven der Stationen Pawlowsk, Wilhelmshaven und Süd-Georgien hier mitgeteilt seien. Unter den anderen Stationen ist keine, welche den erhaltenen Resultaten widerspräche.

U_1 (Figur 4). 1 mm = 1°.8. Die Verläufe sind ähnlich, doch haben sie im Gegensatz zu ihren Amplituden, u_1, die Extreme zur selben Zeit, d. i. das Maximum im nördlichen Winter, das Minimum im nördlichen Sommer. Berechnet man die Extreme der Welle w_1, so findet man, dass jedesmal im Sommer die Ursache der Welle w einen grösseren Einfluss ausübt, als im Winter.

U_2 (Figur 5). 1 mm = 1°.8. Während die Verläufe der u_2 auf der südlichen Hemisphäre ganz andere waren, als auf der nördlichen, sind die der U_2 dieselben; man kann sie durch Spiegelung um den Mittelwert in einander umwandeln.



FIGUR 5. (U_2)



FIGUR 6. (U_3)

U_3 (Figur 6). 1 mm = 18°. Der Gang ist entgegengesetzt und zweifachperiodisch; eine Phasen-Verschiebung scheint trotzdem nicht zu bestehen.

Aus dem Vergleich dieser Curven folgt, dass die jährlichen Verläufe der niederen Coeffizienten einfach und wohl ausgesprochen sind, dass sie nicht an jedem Orte anders gestaltet, sondern ein-

Digitized by Google

ander ähnlich sind, und schliesslich, das zwischen der Welle *w* und den anderen ein prinzipieller Unterschied besteht. Letzteres ist auch noch daraus zu erkennen, dass die U_2 U_3 im Gegensatz zu U_1 mit abnehmenden Werten der Amplituden ebenfalls abnehmen.

Dieser Unterschied der Welle *w* gegen die anderen bestätigt sich, wenn man auf die Wiedergabe der Extreme des täglichen Verlaufes der Declination eingeht. Man kann unschwer an den Curven der Declinations-Variationen in unseren Breiten ausser den Haupt-Extremen noch eine Reihe von Neben-Extremen constatieren, die sich bei näherer Betrachtung als bedeutend gesetzmässigere Erscheinungen herausstellen, als man wohl erwartete. Die Zahlen der beigefügten Tabelle geben die Eintrittszeiten der Extreme der östlichen Declination zu *Pawlowsk* nach dortiger mittlerer Ortszeit. Die grösste östliche Elongation entspricht dem Maximum erster Ordnung, die zweitgrösste dem zweiter u. s. w. Entsprechend ist das Minimum z. B. vierter Ordnung der östlichen Declination das viertgrösste Minimum. In *Pawlowsk* ist die Declination etwa 1° westlich, doch beziehen sich in dieser Arbeit alle Werte auf östliche Declination, da dies durch die Wahl der Vorzeichen der Coordinaten-Achsen bedingt ist.

EINTRITTSZEITEN DER MAXIMA DER OESTLICHEN DECLINATION ZU PAWLOWSK.

Monat Ordnung.	1882 VIII	IX	X	XI	XII	1883 I	II	III	IV	Mittlere Ortzeit. V	VI	VII	Jahr.
	h												
1	7.8	8.1	22.3	21.3	22.3	21.3	0.3	22.1	8.3	7.3	7.3	7.8	8.3
2	1.3	21.3	1.6	1.3	2.3	23.6	22.6	8.6	2.3	1.3	1.3	2.6	21.8
3	22.3	23.6	8.6	5.3	9.3	1.3	20.6	19.6	4.8	21.6	0.1	23.3	23.3
4	20.3	1.3	4.6	9.6	16.3	8.8	18.3	3.1	3.6	18.3	21.3	19.6	1.6
5		4.1	18.1	3.6	7.3	4.8	9.3	5.6	22.1		17.8		4.6
6						18.3	5.8	14.3	19.6				

MINIMA DER OESTLICHEN DECLINATION.

1	13.8	13.8	14.3	13.6	12.8	13.3	14.3	14.4	14.1	13.6	14.3	14.6	13.3
2	3.6	2.3	3.6	7.3	6.3	19.6	4.3	15.3	20.6	19.6	19.3	20.6	3.1
3	22.1	20.3	5.8	4.6	17.3	7.6	6.8	0.6	22.6	22.6	22.6	0.3	5.3
4	0.3	5.3	19.3	2.6	8.3	3.3	18.3	4.3	3.6	2.3	0.3	3.3	0.6
5		0.6	0.3	0.8	0.3	1.1	21.3	7.3	5.6		2.3		22.8
6		22.6				22.6	23.3	20.3					

Die Uebersicht der Extreme zeigt, wie zu gewissen Tages-Zeiten (z. B. 7–8^h ein Maximum, 23^h–0^h ein Minimum) in *jedem* Monate Extreme eintreten, die aber im Laufe des Jahres in sehr hohe Ordnungen zurückgedrängt werden können, so dass selbst diese Extreme 4ter bis 6ter Ordnung nicht blosse Zufälligkeiten sind. Bekannt ist namentlich das Verhalten der um $8^h.3$ und $23^h.3$ (im

Digitized by Google

Jahres-Durchschnitt) auftretenden Maxima; sie tauschen ihre Rolle wechselseitig, indem sie im Laufe des Jahres folgende Ordnungen annehmen:

	Jahr	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII
$8^h.3$	1	1	1	3	4	3 oder 5	4	5	2	1	1	1	1
23.3	3	3	3	1	1	1	2	1 und 2	1	5	–	3	3

Das heisst: im Winter wirken der Tendenz, um 8^h ein Maximum zu bilden, irgend welche Kräfte entgegen. Diejenige Welle w_1, welche dieses Extrem erzeugt, muss also im Winter nicht wirken können. Dessen werden wir uns nachher zu erinnern haben.

Berechnet man nun die Eintrittszeiten der Welle w, und vergleicht sie mit den beobachteten Extremen, so ergiebt sich der Vergleich:

Monat		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Jahr
		h												
Maximum	ber.	3.6	2.8	0.7	22.8	23.8	0.1	0.3	2.2	3.6	3.9	4.2	4.2	4.0
"	beo.	1.3	1.3	1.6	21,3	22.3	23.6	0.3	3.1	3.6	1.3	1.3	2.6	4.6
Ordnung		2	4	2	1	1	2	1	4	4	2	2	2	4
Differenz		—2.3	—1.5	0.9	—1.5	—1.5	—0.5	0.0	0.9	0.0	—2.6	—2.9	—1.6	0.6
Minimum	ber.	15.6	14.8	12.7	10.8	11.8	12.1	12.3	14.2	15.6	15.9	16.2	16.2	16.0
"	beo.	13.8	13.8	14.3	13.6	12.8	13.3	14.3	14.4	14.1	13.6	14.3	14.6	13.3
Ordnung		1	1	1	1	1	1	1	1	1	1	1	1	1
Differenz		—1.8	—1.0	1.6	2.8	1.0	1.2	2.0	0.2	—1.5	—2.3	—1.9	—1.6	—2.7

w_1 allein stellt also die Haupt-Extreme nicht dar, hat jedoch einen grossen Anteil an ihrer Erzeugung. Die Darstellung des Maximums ist am genauesten im Winter; w_1 ist also ganz besonders von den Ursachen abhängig, welche das oben besprochene 8^h Maximum zu stande bringen wollen. Deshalb entsprechen auch im Sommer dem berechneten Extrem von w_1 nur beobachtete hoher Ordnung. Die Wiedergabe des Minimums ist so, dass das berechnete im November und Dezember vor der Culmination der Sonne, von October bis März jedenfalls vor dem beobachteten liegt; die Welle w_1 hat also stets das Bestreben, das Extrem der täglichen Variation der Culminationszeit der Sonne näher zu bringen. Dies ist unvereinbar mit einer rein meteorologischen Natur der Welle, die immer von der Culmination wegtreibt, aber ganz in Uebereinstimmung, einerseits mit dem Zurücktreten des Einflusses von w_1 beim Sommer Maximum und andererseits mit dem der jährlichen Verläufe der u_1 und U_1 auf beiden Hemisphären w_1 ist der einzige Anteil, der auf gleichen nördlichen und südlichen Breite gleiche Amplituden hat. Das dürfte nicht der Fall sein, wenn w_1 meteorologischer Natur im gewöhnlichen Sinne wäre. Was dieser Zusatz bedeutet, werden wir später sehen.

Digitized by Google

Die Welle w_2 hat je zwei Maxima und Minima. Ordnet man wieder zu jedem berechneten das beobachtete Extrem zu, das ihm zeitlich am nächsten kommt, so hat man nachstehende Uebersicht:

w_2

Monat		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Jahr
		h												
I. Maximum	ber.	8.7	9.1	9.7	10.5	11.9	10.5	11.2	9.5	9.0	7.5	7.9	8.3	8.4
"	beo.	7.8	8.1	8.6	9.6	9.3	8.8	9.3	8.6	8.3	7.3	7.3	7.8	8.3
Ordnung		1	1	3	4	3	4	5	2	1	1	1	1	1
Differenz		—0.9	—1.0	—1.1	—0.9	—2.6	—1.7	—1.9	—0.9	—0.7	—0.2	—0.6	—0.5	—0.1
II. Maximum	ber.	20.7	21.1	21.7	22.5	23.9	22.5	23.2	21.5	21.0	19.5	19.9	20.3	20.4
"	beo.	20.3	21.3	22.3	21.3	22.3	23.6	22.6	22.1	22.1	18.3	21.3	19.6	21.8
Ordnung		4	2	1	1	1	2	2	1	5	4	4	4	2
Differenz		—0.4	0.2	0.6	—1.2	—1.6	0.9	—0.6	0.6	1.1	—1.2	1.4	—0.7	1.4
I. Minimum	ber.	14.7	15.1	15.7	16.5	17.9	16.5	17.2	15.5	15.0	13.5	13.9	14.3	14.4
"	beo.	13.8	13.8	14.3	13.6	17.3	19.6	18.3	15.3	14.1	13.6	14.3	14.6	13.3
Ordnung		1	1	1	1	3	2	4	2	1	1	1	1	1
Differenz		—0.9	—1.3	—1.4	—2.9	—0.6	3.1	1.1	—0.2	—0.9	0.1	0.4	0.3	—1.1
II. Minimum	ber.	2.7	3.1	3.7	4.5	5.1	4.5	5.2	3.5	3.0	1.5	1.9	2.3	2.4
"	beo.	3.6	2.3	3.6	4.6	6.3	3.3	4.3	4.3	3.6	2.3	2.3	3.3	3.1
Ordnung		2	2	2	3	2	4	2	4	4	4	5	4	2
Differenz		0.9	—0.8	—0.1	0.1	1.2	—1.2	—0.8	0.8	0.6	0.8	0.4	1.0	0.7

Wir fanden oben, dass die jährlichen Verläufe der u_2, U_2 sich ganz anders verhalten, als die der u_1, U_1 und müssen Aehnliches auch hier finden. w_2 ist wie w_1 an den Haupt-Extremen beteiligt, jedoch mit dem Unterschiede, dass die Darstellung eine bessere und zwar namentlich im Sommer ist. Das I. Minimum von w_2 tritt *stets nach* der Culmination der Sonne ein, und nur Mai, Juni und Juli liegt es später als das beobachtete; es entfernt also vom Mittage. Das Minimum II. stellt das $3.^h1$ Extrem im Jahres-Durchschnitt dar, im Winter in höheren Ordnungen, also nicht so wirksam.

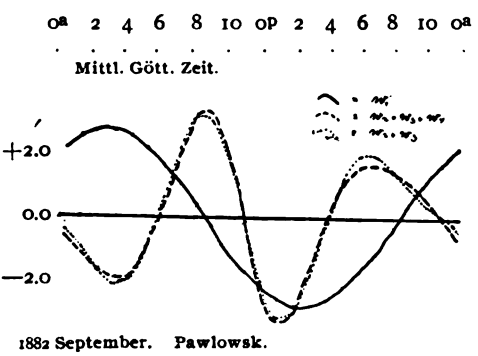
Das oben besonders hervorgehobene Morgen-Maximum um $8.^h3$ wird mit ziemlich gleicher Genauigkeit allein von w_2 übernommen; folglich gelten die oben gemachten Schlüsse für w_2: *sein Einfluss tritt im Winter zurück gegen den von* w_1. Mit dem ist auch das Verlegen der Hauptwirkung von w_2 auf den Nachmittag in Einklang, sowie die Verschiedenheit der jährlichen Verläufe der u_2, U_2 in Amplitude und Gestalt auf beiden Hemisphären. Hier käme demnach, wenn überhaupt, der verschiedene meteorologische Character südlicher und nördlicher Breiten zum Ausdruck.

Die Extrem-Wiedergabe durch w_3 kann über die Natur dieser an Betrag kleinen Welle nichts Bestimmtes aussagen, da die hier angewandte Methode der Extrem-Darstellung nur für Wellen mit gleicher Grössenordnung der Amplituden Resultate geben kann.

Digitized by Google

Um zu finden, wie die einzelnen Wellen in die *Herstellung der Amplituden* der täglichen Variation eingreifen, wurde der Einfluss jeder Welle einzeln berechnet. Das Ergebnis war, im Verein mit den schon erhaltenen Resultaten, dass die tägliche Variation der Declination aus zwei verschiedenen Anteilen besteht, von denen der eine vom meteorologischen Unterschied zwischen Tag und Nacht, Sommer und Winter, Nord- und Süd-Hemisphäre unabhängig ist, der andere nicht. Der erstere Anteil wird durch w_1, der zweite durch die Summe der übrigen Wellen repräsentiert, sehr gut jedoch schon von $w_2 + w_3$ allein wiedergegeben.

Dies veranschaulicht das Beispiel (Figur 7) der unten wiedergegebenen Curven für den Monat September 1882, *Pawlowsk*. w_1 ist natürlich eine reine Sinus-Welle und bietet weiter nichts Interessantes dar. An der Combinationswelle $w_2 + w_3$ und $w_2 + w_3 + w_4$ erkennt man jedoch, dass thatsächlich die Welle w_4 und selbstverständlich auch die folgenden die Gestalt der Wellencombination $w_2 + w_3$ kaum ändert. Und dabei ist das Beispiel einem Winter-Monat entnommen, wo alles viel unregelmässiger ist, als im Sommer. Wären die u_2, u_3, u_4 u. s. w. vollständig dem Zufall unterworfen, so würde der Fall, dass die Hinzunahme einer weiteren Welle die Gestalt der Combination nicht ändere, *einer* unter unendlich vielen sein. *De facto* ergiebt sich aber für jeden Monat in Pawlowsk und für jede Station, welche denselben Verlauf der u_k wie *Pawlowsk* hat, dieselbe Gestalt der Combinations-Welle; mithin hat sie reale Existenz, im selben Sinne, wie etwa die zweite Welle des Luft-Drucks, eine reale Bedeutung hat, indem diese stehenden Schwingungen in der Atmosphäre entspricht.



FIGUR 7.

Im Anschlusse hieran sei bemerkt, dass beim täglichen Verlaufe des Luft-Druckes sich herausstellt, dass die Combinations-Welle $w_2 + w_3 + w_4$ fast gar nicht von der Welle w_2 allein genommen verschieden ist. Das sagt eben aus, dass der Luft-Druck im Wesentlichen nur aus w_1 und w_2 besteht. Nach Werten, die mir mein College, Herr *W. Kühl*, freundlichst zur Verfügung stellte, zeigt

Digitized by Google

der tägliche Gang der Boden-Temperatur in Pawlowsk für 1 m Tiefe wieder eine Combinations-Welle $w'_2 + w'_3$, die die gleiche Gestalt hat, wie die Welle $w_2 + w_3$ des täglichen Ganges der *westlichen* Declination am selben Orte. Vielleicht kann dieser Umstand für weitere Untersuchungen von Wert sein.

Wir haben also neben der 24-stündigen Sinus-Welle eine andere, ebenfalls 24-stündige, die das einfache Gesetz hat, dass sie gleich $w_2 + w_3$ ist. Hiermit sehen wir zugleich, welche Rolle w'_3 spielt: es unterstützt w'_2. Zwischen diesem und w'_1 fanden wir aber durchgängig eine prinzipielle Verschiedenheit und müssen daher die Combinations-Welle anderen Ursachen zuschreiben, als die Welle w'_1. Dies gilt nicht nur für Pawlowsk, sondern auch für die anderen betrachteten Stationen, nicht nur für 1882–83, sondern auch für die Jahre 1883–89, wie die Analyse der *Greenwicher* Beobachtungen durch *Sack* gezeigt hat, nach *Hiratsuka*,[1] sogar für *Tokio* 1897, also wohl für jedes Jahr. Es ist auch nicht auf die Declination beschränkt. Dann bedenkt man, dass

$$\Delta\delta = \frac{c}{H}(\cos\delta\,\Delta Y - \sin\delta\,\Delta X)$$

so lässt sich leicht zeigen, dass

$$\left(u_n\right)_\delta = \frac{c}{H}\left[\cos\delta\,(u_n)_Y - \sin\delta\,(u_n)_X\right.$$

wo $(u_n)_\delta$ die Amplitude der Welle w_n für Declination, $(u_n)_Y$ für die Welle w_n des täglichen Verlaufes der Ost-West-Componente, $(u_n)_X$ für die gleiche Welle der Variationen der Nord-Süd-Componente ist. Die U_n sind aus den p_n, q_n zu berechnen, die denselben Gesetzen gehorchen wie die u_n. *Bezold* hat gezeigt, dass aus ΔX und ΔY für alle Punkte der Erde das Potential des täglichen Feldes berechnet werden kann, *folglich besteht das ganze Kraftfeld der täglichen Variation aus zwei Anteilen.*

Hier möchte ich auf eine neuere Arbeit von *G. Sack*[2] hinweisen, die durch ihre eingehenden Betrachtungen in Bezug auf die tägliche Variation der Inclination und Total-Intensität in *Greenwich* und *San Mayen* für weitere Untersuchungen über die Bestandteile des täglichen Feldes von grosser Bedeutung ist. So verschieden die täglichen Verläufe selbst an beiden Orten sind: die harmo-

[1] HIRATSUKA. Harmonische Analyse der täglichen Variation der Declination zu Tokio 1897. Meteorol. Zeitschr. XVI, 178–180. 1899.

[2] G. SACK. Ein Beitrag zur Untersuchung der täglichen Variation der Inclination und Total-Intensität. Progr. d. Katharineum. Lübeck 1901.

Digitized by Google

nischen Wellen ergeben deutlich einen an beiden Orten gleichen Gegensatz zwischen w_1, und $w_2 + w_3$.

Es ist ja bekannt, dass schon *Ad. Schmidt*[1] eine Doppelnatur der Amplitude der täglichen Variation gefunden hat, indem er sie in ihrer Abhängigkeit von der Sonnen-Fleckenzahl untersuchte. In jüngster Zeit hat auch *Angot*[2] zwischen einer "onde normale" und einer "onde perturbatrice" unterschieden, von denen die erstere dem fleckenlosen, die letztere dem Flecken-Zustand der Sonne entspricht. Auch dieser Forscher findet eine vollkommen verschiedene Natur der beiden Anteile und kommt zu dem Schluss, dass beide irdischen Ursprungs sind. Ein direkter Sonnen-Einfluss wäre ja auch nur denkbar in Art der eingangs erwähnten Elektronen-Emanationstheorien.

Die Resultate der vorliegenden Arbeit, sowie die der angeführten anderen sprechen alle dafür, dass *der eine Anteil dem solaren, der andere dem terrestrischen die Gesamtvariation dem physischen Klima entspricht, also lediglich irdischer und speziell meteorologischer Natur ist.*

Diese qualitative muss durch eine quantitative Untersuchung ergänzt und befestigt werden. Da es fraglich ist, ob man in Bälde dieser Aufgabe gerecht werden wird, so sei mir gestattet, nur kurz anzudeuten, wie man hier vorgehen kann.

Gesetzt man vermute einen Zusammenhang zwischen der Welle w_n im täglichen Verlaufe eines Elementes e mit dem gleichen Verlaufe eines anderen Elementes e; sind dann $(p_n)\,e$ $(q_n)\,e$ $(p_n)\,\epsilon$ $(q_n)\,\epsilon$ die entsprechenden Coeffizienten in der Cosinus-Sinusform, so ist

$$(p_n)_e = k\,(p_n)_\epsilon \qquad (q_n)_e = k\,(q_n)_\epsilon$$

wenn $e = k\epsilon$ die Relation zwischen e und ϵ für irgend ein Wertepaar. Dasselbe gilt für die Coeffizienten P_n Q_n des jährlichen Verlaufes

$$(P_n)_e = k\,(P_n)_\epsilon\,, \quad (Q_n)_\epsilon = k\,(Q_n)_\epsilon$$

Und ist schliesslich $e\phi\lambda = f(e_o, \phi, \lambda)$ wo e_o irgend ein Ausgangswort, ϕ und λ aber Breite und Länge, so muss ebenfalls sein

$$(p_n)_{e\phi\lambda} = k\,(p_n)_{\epsilon\phi\lambda}$$

$$(P_n)_{e\phi\lambda} = k\,(P_n)_{e\phi\lambda}$$

plus zwei ähnliche Gleichungen in q und Q. Dies ist nichts weiter, als der Satz, dass ϵ stets dieselbe Function von e ist. Hieraus

[1] AD. SCHMIDT. Wiener Sitzungsber. 1888.
[2] A. ANGOT. Compt. Rend. CXXXII. 1901 Paris.

Digitized by Google

kann man aber für jedes meteorologische oder geophysicalische Element, von dem man weiss, dass irgend einer seiner Werte eine bestimmte (jedoch lineare) Function einer gegebenen Zahl anderer Elemente ist, seine harmonische Constituenten, d. h. seinen Verlauf vorausberechnen, falls man weiss, wie die Elemente variieren, von denen es abhängt, und ihre Anzahl kennt. Die einfachste Fassung dieses Coeffizienten-Satzes ist wohl die, dass *die Variationen des secundären Elementes von denen der primären so abhängen müssen, wie die absoluten Werte, um welche die Schwingungen stattfinden, von einander abhängen.*

Dies auf die tägliche Variation der Declination angewandt, würde nun verlangen, dass diejenige Welle, welche dem solaren Klima entsprechen soll, mit der Tages-Zeit, mit der Jahres-Zeit und mit der Breite so variiert, wie das solare Klima mit diesen Momenten variiert; entsprechendes würde für das physische magnetische Klima gelten. Es ist schon oben gezeigt, dass w_1 und $w_2 + w_3$ sich in Bezug auf Tages- und Jahres-Zeit so verhält; die Abhängigkeit von der Breite ist noch nicht untersucht worden, da das bis jetzt vorhandene Material noch nicht ausreicht, sich aber in kurzer Zeit sehr beträchtlich vermehren dürfte.

Um aber quantitative Beziehungen zu bekommen, muss man den Zusammenhang zwischen den Coeffizienten $(p_n)_{e_1}$, $(p_n)_{e_2}$ . . . . $(p_n)_{e_m}$ der Elemente $e_1, e_2 \ldots e_m$, welche das solare Klima darstellen, nach obigen Formeln mit dem $(p_n)_\delta$, d. i. dem Coeffizienten der Declination vergleichen. Nur solche Hypothesen haben dann eine Berechtigung, bei denen der jährliche, der tägliche und der Verlauf längs eines Meridians stets dieselbe Abhängigkeit zwischen den Coeffizienten ergeben. Sollte irgend eine Annahme nicht zu diesem Resultat führen, so existiert kein causaler Zusammenhang zwischen den verglichenen Verläufen. Ganz besonders möchte Verfasser noch darauf hinweisen, dass es mit Hülfe des entwickelten Verfahrens gelingen wird, manche in der Literatur vertretene Vermutung eines causalen Zusammenhanges zwischen geophysicalischen Variationen zu widerlegen, die lediglich über die elfjährige Sonnenflecken-Periode hinüber abgeleitet wurde. Da es wohl kaum irgend eine irdische Erscheinung geben dürfte, die nicht dieser Periode von 11 Jahren unterworfen ist, so kann gerade sie gar nichts über die Causalität eines von ihr erwiesenen Zusammenhanges aussagen.

Besonders einfach wird die Aufgabe, falls man auf dem beschriebenen Wege nicht gewissermassen tastend vorgeht, sondern

Digitized by Google

bestimmte Ideen zu Grunde legt. Geht man z. B. davon aus, dass die Variationen des Erdmagnetismus lediglich durch electrische Ströme in der Atmosphäre hervorgerufen werden, so müssen wir als Ursache ihrer Variabilität diejenige des Potential-Gefälles und der Leitfähigkeit der Luft annehmen. Nennen wir die erstere v, die letztere l und die Stromstärke i, so verlangt der Coeffizienten-Satz, dass $(p_n)\, i = v_o\,(p_n)_l + l\,(p_n)\, v$. Die Abhängigkeit der Leitfähigkeit von dem Zustand der Luft (Dichte, Temperatur, Grad der Ionisation, Feuchtigkeits-Gehalt etc.) kann im Laboratorium untersucht werden. Variiert dann eine der Zustands-Grössen um einen bestimmten Betrag, so ist die Variation von l damit gegeben, d. h. auch die Aenderung von $(p_n)_l$. Aehnlich liegen die Dinge bei $(p_n)_v$. Es ist dabei vollkommen einerlei, warum die Aenderungen eintreten, d. h. desshalb vielleicht, weil ihre tägliche oder ihre jährliche Periode existiert, weil man in andere Breiten geht oder sich von der Erd-Oberfläche entfernt: immer erhält man die Coeffizienten der Stromstärke mit Hülfe des angeführten Satzes, falls man nur das Gesetz kennt, das für irgend ein Werte-Paar v, l das i giebt. Erklären die so berechneten Variationen in der Strom-Stärke und die ähnlich erhaltenen der Strom-Richtung die Variationen der erdmagnetischen Elemente quantitativ, sowohl von Stunde zu Stunde als auch von Tag zu Tag und Ort zu Ort, so sind solche Ströme die wahre Ursache. Der Vorteil des Verfahrens beruht darin, dass man sich nicht auf die ganzen Verläufe stützen muss, sondern dass die Kenntnis der Coeffizienten genügt.

De facto sind die Einflüsse electrischer Ströme in der Atmosphäre auf den Erdmagnetismus schon durch die Induction im Erdboden complizierter, wie es denn überhaupt von vornherein klar ist, dass die zu lösende Aufgabe nicht in Kürze zu erledigent ist.

Digitized by Google

WORK IN TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY IN SOUTH AFRICA.

J. C. BEATTIE.

In December, 1897, Professor Morrison and the writer began, at their own expense, a preliminary magnetic survey in South Africa. Their first journey was from Cape Town to Bulawayo; later they made another long journey from Cape Town via de Aar and Cradock to Port Elizabeth. In this first year of observational work the dip and horizontal intensity were determined. The declination observations turned out to be valueless.

In 1898 the Government Grant Committee of the London Royal Society voted a sum of money to carry on the work begun by these two observers. The Government of Cape Colony, through the Department of Public Works, also gave a grant of money in addition to giving facilities for railway journeys. Since that time the work has been liberally supported financially. It has been possible to obtain a second complete set of the Kew field instruments. A five-inch theodolite, a chronometer, and a suitable tent have also been added to the equipment. Observations have been made of the declination, dip, and horizontal intensity at eighty-four stations in all. It has not yet been possible, unfortunately, to start any station with a set of self-recording instruments. There is no doubt, however, that the governments in South Africa, with their liberal views of the support to be given to scientific work, will in time found several such stations, suitably distributed in Africa south of the Zambesi.

During the year 1903 the writer proposes to try to bring this preliminary survey to a conclusion. The observations will be carried out at a number of additional stations in the northwest and the extreme eastern parts of Cape Colony. In addition a number of observations will be taken in the Transvaal, the Orange River Colony, Natal, and Rhodesia, as well as in German West Africa and Portuguese East Africa. The total number of stations, it is hoped, will finally be over two hundred. It is hoped that it will be possible to give a fairly good idea of the values of the various elements as far north as the Zambesi after all the data from these observations have been collected.

The observations of atmospheric electricity in South Africa are as yet very few. At present Mr. Logeman, at the South African College, Cape Town, is taking a daily series of readings with a "zerstreuungs apparatus," as designed by Elster and Geitel. He also proposes to take a parallel set of readings with a Kelvin portable electrometer. These observations will be carried on for a year. Mr. Lyle, of Grey College, Bloemfontein, also proposes to carry out a similar series of observations in Bloemfontein.

South African College, Cape Town, South Africa.

Digitized by Google

WILSON'S GIBB'S VECTOR ANALYSIS.[1]

By Professor E. W. Hyde.

As an enthusiastic believer in the value and usefulness of vector and point analysis, I can not avoid a feeling of regret that several different systems of notation should be in use to express identical or very similar ideas. The general introduction and use of directional methods of operation must certainly be hindered by such a state of affairs. The vector system of Professor Gibbs, which is already familiar to some through the pamphlets on the subject printed by him for private distribution some years ago, agrees to some extent with that of Grassmann, though the notation and some of the fundamental ideas are different. Every relation treated in this book can be as well, and often more simply, expressed in a notation differing from that of Grassmann only in the omission of the brackets surrounding combinatory products, which seem to me unnecessary. For instance, $\mathbf{a} \cdot \mathbf{b} \times \mathbf{c}$, $\mathbf{a} \times (\mathbf{b} \times \mathbf{c})$, $(\mathbf{a} \times \mathbf{b}) \times (\mathbf{c} \times \mathbf{d})$, $(\mathbf{a} \times \mathbf{b}) \cdot (\mathbf{c} \times \mathbf{d})$ are equivalent in Grassmann's notation to $\mathbf{a\,b\,c}$, $\mathbf{c\,b \mid a}$, $\mathbf{a\,b \cdot c\,d}$, $\mathbf{a\,b \mid c\,d}$.[2]

The geometrical ideas underlying the Gr. forms are somewhat different, more general, and, to my mind, simpler than those involved in the G. notation.

One or two general features of the book may be mentioned here. The use of a special type for vectors is a very convenient thing in a printed book, and practically doubles the available supply of letters, but has its drawbacks for class use. It would be difficult for a teacher using this text-book to follow its notation in this respect in his blackboard work. He would be obliged to underscore his vectors, use Greek letters, or something of the sort. By the way, the author has avoided the use of Greek letters, except π occasionally, and the functional symbols Φ and Ψ; an unusual thing in a mathematical work. Even angles are represented by q.

[1] *Vector Analysis.* A text-book for the use of students of Mathematics and Physics, founded upon the lectures of J. Willard Gibbs, Ph. D., LL. D., Professor of Mathematical Physics in Yale University, by Edwin Bidwell Wilson, Ph. D., Instructor in Mathematics, Yale University.

[In view of the increasing use of the methods of vector analysis by students of magnetism and electricity, the above review by a leading authority on the subject will no doubt prove welcome to the readers of this Journal who have occasion to deal with the theoretical discussion of problems of the Earth's magnetic and electric conditions.—Ed.]

[2] Hereafter, when it is desired to designate the notations of Hamilton, Grassmann, and Gibbs, they will be respectively denoted by the letters H., Gr., and G.

Digitized by Google

A useful feature of the work is the conclusion of each chapter, except the last, by a summary of its contents. A collection of exercises is also appended to each chapter, except the sixth and seventh. It would have added to the convenience of the book for practical purposes if the chapter were given on each page as part of the running head.

We will now take up the successive chapters and sketch their contents.

Chapter I is devoted to vector addition and subtraction. The treatment is very full and complete; in fact, as fifty-four pages are comprised in this chapter, it may be regarded as perhaps unnecessarily prolix for a subject so simple and familiar as this. Attention is called to the fact that a vector expression, such as

$$\mathbf{r} = \frac{\Sigma m \mathbf{a}}{\Sigma m}$$

is independent of any particular origin, and therefore expresses a relation between the extremities of the vectors $\mathbf{a}_1$, $\mathbf{a}_2$, etc., so that the vectors may be replaced by points at their extremities.

Chapter II comprises sixty pages, 55–114 inclusive, and treats products of vectors, variously designated as direct and skew, or scalar and vector, or dot and cross. A direct, scalar, or dot product of a and b is written $\mathbf{a} \cdot \mathbf{b}$, and is equivalent in H. notation to $-S\mathbf{a}\mathbf{b}$, and in Gr. notation to $\mathbf{a} \mid \mathbf{b}$. It seems to me that either Hamilton's or Grassmann's way of arriving at this expression is more satisfactory than the definition as given on page 28, which is likely to strike a student as somewhat arbitrary, no particular reason being apparent why $a\,b \cos(\mathbf{a}, \mathbf{b})$ should be called a product of a and b. The skew product (vector, cross) is written $\mathbf{a} \times \mathbf{b}$, and is equivalent to $V\mathbf{a}\mathbf{b}$ and $\mid \mathbf{a}\,\mathbf{b}$ respectively in H. and Gr. notation. It is defined on page 60 as "the vector quantity c whose direction is the normal upon that side of the plane of a and b on which rotation from a to b through an angle of less than 180° appears positive or counterclockwise; and whose magnitude is obtained by multiplying the magnitudes of a and b by the sign of the angle from a to b." This certainly does not compare for simplicity with Grassmann's conception, which is that the combinatory product $\mathbf{a}\,\mathbf{b}$ is simply the directed parallelogram determined by the two vectors. The complement of this, $\mid \mathbf{a}\,\mathbf{b}$, is Professor Gibbs's product. In fact, it seems to me that nothing can exceed, in sim

Digitized by Google

plicity, naturalness, and generality Grassmann's fundamental idea of a combinatory product of directed or posited quantities, viz., that which is fixed or determined by them. In connection with the idea of the complement it covers every case of combinatory multiplication, whether the product be scalar or non-scalar.

The laws of direct and skew multiplication are fully explained, and illustrated by application to various relations of geometry and mechanics. Formulæ of reduction are derived, and the relations between two systems of mutually perpendicular unit vectors are investigated. Particular attention is paid to reciprocal systems of vectors; *i. e.*, systems related as are the radii to the vertices of a spherical triangle and its polar. If a, b, c and a′, b′, c′ are such systems, then we have $\mathbf{a}' = \frac{\mathbf{b}\times\mathbf{c}}{[\mathbf{a}\,\mathbf{b}\,\mathbf{c}]}$, etc.

The relations $\mathbf{a} = \frac{\mathbf{b}'\times\mathbf{c}'}{[\mathbf{a}'\mathbf{b}'\mathbf{c}']}$, etc., will also hold, and regarding them the author says, on p. 85, "These relations may be demonstrated directly from the definitions of a′, b′, c′. The demonstration is straightforward, but rather long and tedious, as it depends upon complicated reduction formulæ." Using the Gr. methods the demonstration is as short and simple as could be desired, as follows:

$$\frac{|\,\mathbf{b}'\mathbf{c}'}{\mathbf{a}'\mathbf{b}'\mathbf{c}'} = \frac{\mathbf{c}\,\mathbf{a}\cdot\mathbf{a}\,\mathbf{b}}{(\mathbf{a}\,\mathbf{b}\,\mathbf{c})^2} \qquad \frac{(\mathbf{a}\,\mathbf{b}\,\mathbf{c})^2}{\mathbf{a}\,\mathbf{b}\cdot\mathbf{b}\,\mathbf{c}\cdot\mathbf{c}\,\mathbf{a}} = \frac{\mathbf{a}\,\mathbf{b}\,\mathbf{c}\cdot\mathbf{a}\cdot\mathbf{a}\,\mathbf{b}\,\mathbf{c}}{(\mathbf{a}\,\mathbf{b}\,\mathbf{c})^2} = \mathbf{a}, \text{ Q.E.D.}$$

With respect to these reciprocal systems it may be noted that $\frac{\mathbf{b}\times\mathbf{c}}{[\mathbf{a}\,\mathbf{b}\,\mathbf{c}]}$ is only one of an infinite number of reciprocals of a, viz.:

$$\mathbf{a}'' = \frac{l\,\mathbf{b}\times\mathbf{c} + m\,\mathbf{c}\times\mathbf{a} + n\,\mathbf{a}\times\mathbf{b}}{l\,[\mathbf{a}\,\mathbf{b}\,\mathbf{c}]},$$

in which the scalar constants l, m, n may have any values whatever; for the dot product $\mathbf{a}\cdot\mathbf{a}''$ is always unity.

The results of this chapter differ only in *form* from those of previous writers on vector analysis. I may be pardoned for giving, before passing to the next chapter, one illustrative comparison as regards *interpretation* of expressions in the H., G., and Gr. notations. We have $\mathrm{V}\cdot\mathrm{V}\,\mathbf{a}\,\mathbf{b}\,\mathrm{V}\,\mathbf{c}\,\mathbf{d}$, $(\mathbf{a}\times\mathbf{b})\times(\mathbf{c}\times\mathbf{d})$, $\mathbf{a}\,\mathbf{b}\cdot\mathbf{c}\,\mathbf{d}$ as expressions of identical meaning; *i. e.*, each is precisely the same vector. The H. and G. expressions are to be interpreted also by

Digitized by Google

exactly the same statement, viz.: A vector which is perpendicular to two vectors, of which one is perpendicular to both **a** and **b**, and the other to both **c** and **d**. For the third expression we have simply: A vector which is parallel to each of the plane vectors **a b** and **c d**.

Chapter III, pp. 115–178, deals with the differential calculus of vectors. After explaining the differentiation of vector expressions a brief application is made to the curvature and torsion of curves, a subject well adapted to illustrate the advantages of vector methods. The next few pages are devoted to kinematics, circular motion, the motion of a projectile in vacuo, and the path of a particle under action of a central force being treated. The motion of a rigid body having one point fixed is also discussed.

The succeeding thirty-six pages are occupied by a very full and thorough treatment of Hamilton's operator—

$$\nabla = \mathbf{i}\frac{d}{dx} + \mathbf{j}\frac{d}{dy} + \mathbf{k}\frac{d}{dz},$$

for which the name *del* is suggested and used. This seems to the present writer a very happy suggestion, much to be preferred to other names that have been proposed and used by some. The lack of a suitable name for ∇ has probably been felt by all who have had occasion to use the operator in lecture and class work.

The computation of ∇V, in which V is a scalar function of x, y, z, is first explained and illustrated; then the operation ∇ upon a vector function, $\mathbf{V}$, of x, y, z is considered. It is shown that $\nabla \cdot \mathbf{V}$ is the *divergence* of the vector $\mathbf{V}$, written *div* $\mathbf{V}$, and that $\nabla \times \mathbf{V}$ is the *curl* of the same function, written *curl* $\mathbf{V}$. Formulæ are derived for treating the *del* of the products $\mathbf{u} \cdot \mathbf{v}$ and $\mathbf{u} \times \mathbf{v}$, analogous to those of the ordinary calculus for dealing with scalar products. Application is then made to fluid motions, and finally successive applications of ∇ are considered.

Chapter IV, pp. 179–259, deals with the integral calculus of vectors. Beginning with the line integral of a vector function $\mathbf{W}$,

$$\int_c \mathbf{W} \cdot d\mathbf{r},$$

the various theorems regarding such integrals are demonstrated, and conditions for the existence of a force function are determined.

Digitized by Google

As an illustrative example, the case of a body falling under the action of gravity is discussed.

Next a surface integral of a vector function **W** is defined, and Gauss's theorem on the relation between volume and surface integrals is proved, viz.:

$$\int\int\int \nabla \cdot \mathbf{W}\, dv = \int\int_s \mathbf{W} \cdot d\mathbf{a}.$$

Stokes's theorem:

$$\int\int_s \nabla \times \mathbf{W} \cdot d\mathbf{a} = \int_o \mathbf{W} \cdot d\mathbf{r},$$

follows, of which two demonstrations are given, as well as a proof of the converse proposition. Application is made of this theorem to deducing Maxwell's equations of the electro-magnetic field from two facts determined experimentally by Faraday. By the aid of the three fundamental relations,

$$\int_{\mathbf{r}}^{\mathbf{r}} \nabla V \cdot d\mathbf{r} = V(\mathbf{r}) - V(\mathbf{r}_0),$$

$$\int\int_s \nabla \times \mathbf{W} \cdot d\mathbf{a} = \int_o \mathbf{W} \cdot d\mathbf{r},$$

$$\int\int\int \nabla \cdot \mathbf{W}\, dv = \int\int_s \mathbf{W} \cdot d\mathbf{a},$$

a number of integration formulæ are obtained, corresponding with those found by integration by parts in ordinary calculus. Of these the most important is Green's theorem.

Articles 86–96 are devoted to the discussion of potential and three operators formed by combining it with del, designated as the Newtonian, the Laplacian, and the Maxwellian. The abbreviation Pot. V is used for potential of V function of x, y, z, and the other functions are similarly designated as New., Lap., and Max. The relations are then ∇ Pot. V = New. V, $\nabla \times$ Pot. $\mathbf{w}$ = Lap. $\mathbf{w}$, and $\nabla \cdot$ Pot. $\mathbf{w}$ = Max. $\mathbf{w}$. The treatment is very full and complete, and would seem to meet every need along these lines of the student, teacher, or investigator in mathematical physics.

Digitized by Google

Chapter V, pp. 260–331, contains Professor Gibbs's theory of the linear vector function, which is the most original portion of his vector analysis. As his treatment of the subject may be at first a little puzzling to one accustomed to Hamilton's method of dealing with it, a brief statement is here given of the fundamental differences between the two methods.

The general form of a linear vector function in solid space may be written, in H., Gr., and G. notation respectively, as follows:

$$\phi\,\mathbf{r} = \mathbf{a}_1\,S\,\mathbf{b}_1\,\mathbf{r} + \mathbf{a}_2\,S\,\mathbf{b}_2\,\mathbf{r} + \mathbf{a}_3\,S\,\mathbf{b}_3\,\mathbf{r} = \Sigma\,\mathbf{a}\,S\,\mathbf{b}\,\mathbf{r},$$
$$\phi\,\mathbf{r} = \mathbf{a}_1 \cdot \mathbf{b}_1 \mid \mathbf{r} + \text{etc.} \qquad = \Sigma\,\mathbf{a} \cdot \mathbf{b} \mid \mathbf{r},$$
$$\phi.\mathbf{r} = \mathbf{a}_1\,\mathbf{b}_1 \cdot \mathbf{r} + \text{etc.} \qquad = \Sigma\,\mathbf{a}\,\mathbf{b} \cdot \mathbf{r}.$$

In these expressions the operative symbol ϕ represents respectively $\Sigma\,\mathbf{a}\,S\,\mathbf{b}$, $\Sigma\,\mathbf{a} \cdot \mathbf{b} \mid$, and $\Sigma\,\mathbf{a}\,\mathbf{b}$, the distinctive difference being that Professor Gibbs has taken ϕ as representing merely the sum of the pairs of vectors, or dyads, which must be joined to the aperand by a connective sign, while Grassmann has included the connective sign in his ϕ,[1] and Hamilton has done the same of necessity, since the quaternion notation does not admit of its separation.

The fundamental difference of treatment consists in this, that Hamilton has regarded ϕ merely as a functional sombol, so that $\phi_1\,\phi_2\,\rho$ is the ϕ_1 function of the ϕ_2 function of ρ, etc., while Grassmann and Gibbs have regarded it as a symbolic *factor*, so that $\phi\,\rho$ or $\phi \cdot \rho$ is the product of ϕ into ρ, and $\phi_1\,\phi_2\,\rho$, or $\phi_1 \cdot \phi_2 \cdot \rho$, is the continued product of the two symbolic and the vector factors, etc. The formal development of the algebra of these symbolic products is the theme of Chapter V. The method of Professor Gibbs is very different from that of Grassmann. The algebra is linear and associative, coming therefore under the laws laid down in Peirce's *Linear Associative Algebra*. Some of the terms employed in that work are also used by Professor Gibbs.

A word of comparison of what we may call the *factor* and the *function* methods of treatment may not be out of place. Considered from a purely mathematical and theoretical standpoint the *factor* method of Professor Gibbs may be regarded as having advantages over the *function* method of Hamilton. The algebra of dyads and dyadics, as developed by the former, is a beautiful and attractive theory. When, however, we consider the question from the prac-

[1] Grassmann himself uses Q instead of ϕ as his operative symbol.

Digitized by Google

tical side, as regards ease of comprehension and readiness of application by the student to actual problems, a pretty careful examination has convinced me that the advantage is rather with the *function* method. However, the fact that I have myself always used the function method may have some influence on my judgment in the matter. The factor method can be used with the Gr. as well as with the G. notation, a dyad being written $\mathbf{a} \cdot \mathbf{b}$ instead of $\mathbf{a}\,\mathbf{b}$.

We proceed now to review the contents of this chapter. To begin with, a general definition of a linear vector function is given, as satisfying the condition

$$f(\mathbf{r}_1 + \mathbf{r}_2) = f\mathbf{r}_1 + f\mathbf{r}_2.$$

It is shown that such a function may always be written in the form which has been previously given in this article. A *dyad* is defined as two vectors in juxtaposition, and a *dyadic* as a sum of dyads, which is to be represented by Φ, or Ψ, etc. The various properties of dyadics and their conjugators are there demonstrated. By expressing the vectors of a dyadic in terms of the reference system i, j, k, the nonion form is arrived at, viz.—

$$\begin{aligned}\Phi = {} & a_{11}\,\mathbf{i}\,\mathbf{i} + a_{12}\,\mathbf{i}\,\mathbf{j} + a_{13}\,\mathbf{i}\,\mathbf{k} \\ & + a_{21}\,\mathbf{j}\,\mathbf{i} + a_{22}\,\mathbf{j}\,\mathbf{j} + a_{23}\,\mathbf{j}\,\mathbf{k} \\ & + a_{31}\,\mathbf{k}\,\mathbf{i} + a_{32}\,\mathbf{k}\,\mathbf{j} + a_{33}\,\mathbf{k}\,\mathbf{k},\end{aligned}$$

which is sometimes convenient; also a more general nonion form in terms of two sets of three non-coplanar and non-perpendicular vectors.

If $\mathbf{a}\,\mathbf{b}$ be a dyadic, then $\Sigma\,\mathbf{a} \cdot \mathbf{b}$ is called the scalar of the dyadic; and $\Sigma\,\mathbf{a} \times \mathbf{b}$ is called its vector. This scalar is what Hamilton calls m_2 in his theory of $\phi\,\rho$. In Articles 103 and 104 the products of dyadics are discussed. Thus the direct product is defined by the equation

$$(\mathbf{a}\,\mathbf{b}) \cdot (\mathbf{c}\,\mathbf{d}) = (\mathbf{b} \cdot \mathbf{c})\,\mathbf{a}\,\mathbf{d},$$

which appears somewhat arbitrary, since no reason is assigned why it should take this form. The method of arriving at it by regarding $\phi\,\psi\,\mathbf{r}$ as a function of a function of $\mathbf{r}$, seems more natural, and

Digitized by Google

shows at once the reason for the result. Thus if $\psi\,\mathbf{r} = \mathbf{c}\cdot\mathbf{d}\,|\,\mathbf{r} +$ other terms, and $\phi\,\mathbf{r} = \mathbf{a}\cdot\mathbf{b}\,|\,\mathbf{r} +$ other terms, in the Gr. notation; then $\phi\,\psi\,\mathbf{r} = \mathbf{a}\cdot\mathbf{b}\,|\,\psi\,\mathbf{r} +$ etc. $= \mathbf{a}\cdot\mathbf{b}\,|\,\mathbf{c}\cdot\mathbf{d}\,|\,\mathbf{r} +$ etc. $= \mathbf{b}\,|\,\mathbf{c}\cdot\mathbf{a}\cdot\mathbf{d}\,|\,\mathbf{r} +$ etc., a result equivalent to Professor Gibbs's expression, and derived, instead of being assumed. The expression $(\mathbf{a}\,\mathbf{b}) \times (\mathbf{c}\,\mathbf{d})$ is similarly defined as being equivalent to $\mathbf{a}\,(\mathbf{b} \times \mathbf{c})\,\mathbf{d}$, *i. e.*, three vectors in juxtaposition, and is called a *triad*. No meaning or use is, however, assigned to triads and triadics.

Articles 105–114 are occupied with the consideration of the degrees of nullity of dyadics, and of conjugate and reciprocal dyadics. The results obtained are not new, though clothed in unfamiliar forms. In articles 115 and 116 is treated the reduction of the dyadic to the normal form

$$\phi = a\,\mathbf{i}'\,\mathbf{i} + b\,\mathbf{j}'\,\mathbf{j} + c\,\mathbf{k}'\,\mathbf{k},$$

in which $\mathbf{i}, \mathbf{j}, \mathbf{k}$ and $\mathbf{i}'\,\mathbf{j}'\,\mathbf{k}'$ are two systems of mutually perpendicu lar unit vectors. The remainder of the chapter is an exposition o what the author calls double dot and double cross multiplication o dyadics. They are employed for a convenient determination of th invariants of the dyadic, and in the theory of strains in chapter V Two expressions ϕ_2 and ϕ_3 are derived, called respectively t second and third of ϕ, and then ϕ_3 and what is called the scalar ϕ_2 and the scalar of ϕ are the three invariants called by Hamilt m, m_1 and m_2.

Chapter VI contains applications of the theory of the lin vector function to Rotations and Strains. The transformation o by the operator ϕ is such as to produce what is called a homoge ous strain.

ϕ transforms points in space,
ϕ_2 transforms plane areas,
ϕ_3 gives the ratio of change in volume.

If a dyadic be reducible to the form

$$\mathbf{j}'\,\mathbf{j} +$$

it represents a pure axis. Th ditions that this $\phi \cdot \phi_c =$ $\phi_3 > 0$. An oper *rsor*, and the

Digitized by Google

tive of it a *perversor*. If the axis of the versor coincide with i, the versor becomes

$$\mathbf{i}\,\mathbf{i} + \cos q\,(\mathbf{j}\,\mathbf{j} + \mathbf{k}\,\mathbf{k}) + \sin q\,(\mathbf{k}\,\mathbf{j} - \mathbf{j}\,\mathbf{k}),$$

in which q is the angle of version. This is generalized into

$$\mathbf{a}\,\mathbf{a}' + \cos q\,(\mathbf{b}\,\mathbf{b}' + \mathbf{c}\,\mathbf{c}') + \sin q\,(\mathbf{c}\,\mathbf{b}' - \mathbf{b}\,\mathbf{c}'),$$

which is called a *cyclic dyadic*, and produces what is called an elliptic rotation, a, b, c and a′, b′, c′ being two sets of non-coplanar and non-perpendicular vectors. A dyadic reducible to the form

$$\phi = a\,\mathbf{i}\,\mathbf{i} + b\,\mathbf{j}\,\mathbf{j} + c\,\mathbf{k}\,\mathbf{k}$$

produces a pure strain, and is called a *right tensor*. Any dyadic whatever may be expressed as the product of a right tensor and a versor, and therefore any homogeneous strain may be regarded as the combination of a pure strain and a rotation, with or without a perversion. The right tensor and the cyclic dyadic are again generalized into the tonic and the cyclotonic.

Finally the dyadic is discussed by means of the cubic $x^3 - \phi_1 x^2 + \phi_2 x - \phi_3 = 0$, and seven classes are found depending on the nature of the roots of this cubic, and determining different sorts of strain. No exercises are appended to this chapter or to the next.

The seventh and last chapter, pp. 372–436 gives applications of the function theory to Quadric Surfaces, the Propagation of Light in Crystals, and the Curvature of Surfaces, concluding with a brief consideration of bi-vectors, *i. e.*, vectors such as $\mathbf{a} + \mathbf{b}\sqrt{-1}$. The treatment of the quadric surfaces offers nothing essentially different, except as to notation, from that of other writers on vector analysis.

In treating the propagation of light in crystals the author starts with the electro-magnetic equations of the ether in the form

$$\text{Pot.}\frac{d^2\mathbf{D}}{dt^2} + E\,\mathbf{D} + \nabla\,V = 0,$$

$$\nabla \cdot \mathbf{D} = 0.$$

From these are derived other equations suitable for the discussion of the rate of propagation of a plane polarized wave in different directions in a non-isotropic medium. The equation of Fresnel's wave surface is derived, and the relations between the directions and velocities of the ray and the wave front in a non-isotropic medium are discussed.

Digitized by Google

Articles 147–157 contain a discussion of variable dyadics, with the use of the differentiating and integrating symbols ∇, *div.*, *curl.*, *Pot.*, *New.*, *Lap.*, and *Max.*, and this theory is then applied to the treatment of the curvature of surfaces. The equation of the indicatrix is found and the uses of this curve are explained. The usual theorems regarding the curvatures in different sections at a point of the surface are demonstrated. The differential equations of lines of principal curvature and of geodetic lines on a surface are obtained. The mapping of one surface upon another is also treated. In Articles 158–162 bivectors are considered in connection with the integration of the differential equation of harmonic motion.

$$\frac{d^2\,\mathbf{r}}{dt^2} = -\,n^2\,\mathbf{r}.$$

A number of typographical errors have been noted, mostly such as will be readily seen and corrected. One however is quite misleading, viz.: lines 5 and 6, p. 125, should be

$$\mathbf{a}_1 \cdot \mathbf{a}_2 \sim [\mathbf{a}_1 \mid \mathbf{a}_2]$$
$$\mathbf{a}_1 \times \mathbf{a}_2 \sim [\mathbf{a}_1\,\mathbf{a}_2].$$

In the book the complement sign is in the lower right hand expression instead of the upper.

In conclusion, I wish to express my sense of the value of this work both to mathematicians and physicists. I am glad that Professor Gibbs has consented to the publication of methods which he has so long and so successfully used in his lectures. The book will, I am confident, contribute much toward the more general use of vector methods. For such as may prefer a different notation the equations of this work may be easily translated as they are required.

Cincinnati, O.

Digitized by Google

NOTE SUR L'AMPLITUDE DE L'OSCILLATION DIURNE DE LA DÉCLINAISON MAGNÉTIQUE ET SON INÉGALITÉ MENSUELLE.

PAR J. DE MOIDREY, S. J.

L'amplitude de l'oscillation diurne de la déclinaison présente une variation annuelle bien connue: on peut se demander s'il n'y a pas aussi une inégalité mensuelle.

A Zi-ka-wei, l'amplitude est mesurée pour chaque jour sur la courbe photographique elle-même. Comme $1^{mm} = 0'.605$, si on admet qu'un calculateur exercé et soigneux ne se trompe pas de plus de 0^{mm} 2, on pourra estimer que l'amplitude est connue pour chaque jour à 0'.1 près, et indépendamment des erreurs des mesures absolues, du déplacement lent de la base, etc. L'oscillation considérés est toujours celle du milieu du jour, dont l'élongation orientale ou minimum a lieu environ 2 heures aprés le lever du soleil et la digression occidentale, maximum, vers 13^h. De fait, même en hiver, cette ondulation est, à peu près sans exception, la principale.

Afin d'avoir deux périodes de 11 ans, nous nous sommes limités à l'examen de 22 années, 1878–1899. En défalquant quelques courtes interruptions, cela faisait 272 lunaisons.

Toutes les valeurs de l'amplitude, évaluées en dixièmes de minute, ont été rangeés suivant l'âge de la lune, pris simplement dans l'Annuaire du Bureau des Longitudes. Les jours ou l'oscillation n'avait pas pu être mesurée, à cause des perturbations, d'extinction de la lampe, etc. se sont trouvés répartis au hasard, à peu près ègalement entre les divers quantièmes du mois, de sorte que le nombre de valeurs afférentes à chaque date, varie entre les limites assez e'troites de 242 à 257, la moyenne étant 250. La petite inégalité, introduite de ce chef, n'a pas été corrigée, car il est manifeste qu'elle n'a pas d'influence appréciable sur le résultat.

Seul, le 30^e jour de la lune ne possèdait que 133 observations; nous en avons emprunté 58 au 29 et 59 au 1er, pour constituer un 30^e jour factue avec 250 observations.

Le tableau ainsi construit a fourni 30 moyennes, présentant une allure très nette. Ces moyennes, groupées 3 par 3, ont donné 30 moyennes de 3 jours, différant à peine des valeurs primitives.

Digitized by Google

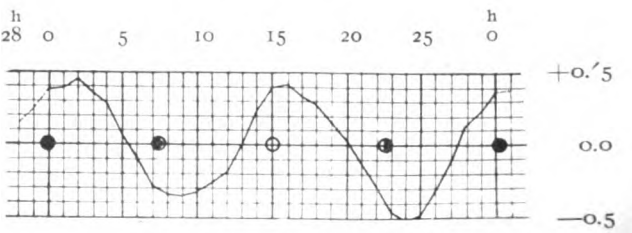
Un tableau semblable avait été établi pour une période de 19 ans, dans la pensée d'éliminer plus sûrement l'influence du soleil: il s'est trouvé tellement semblable au précedent que l'étude n'en a pas été poursuivie.

Les 30 moyennes diurnes, calculées en millièmes, ont pour moyenne 5′.678. Nous donnons le tableau des écarts sur cette moyenne, en les réduisant à 2 décimales.

AMPLITUDE DE L'OSCILLATION DIURNE:
ÉCARTS SUR LA MOYENNE, SUIVANT L'ÂGE DE LA LUNE,
À ZI-KA-WEI.

Age de la lune.	Ecart.	Age de la lune.	Ecart.
0	+0′.37	15	+0′.39
1	+ 0.38	16	+ **0.41**
2	+ **0.45**	17	+ 0.34
3	+ 0.36	18	+ 0.27
4	+ 0.27	19	+ 0.16
5	+ 0.06	20	+ 0.03
6	— 0.10	21	— 0.12
7	— 0.28	22	— 0.27
8	— 0.34	23	— 0.45
9	— **0.35**	24	— **0.52**
10	— 0.33	25	— 0.48
11	— 0.26	26	— 0.32
12	— 0.19	27	— 0.13
13	+ 0.01	28	+ 0.14
14	+ 0.24	29	+ 0.24

Moyenne = 5′.678.



Amplitude de l' oscillation diurne variation pendant la lunaison, à Zi-ka-[illegible]

La double variation de l'amplitude, pend[illegible]ois lunaire, telle qu'elle ressort de ce tableau, est faible [illegible]e régularité évidente. L'amplitude passe par deux mi[illegible]2 jours après les quadratures, et par deux maximums, 2 o[illegible]après les syzygees. Les maximums sont sensiblement èg[illegible]inimum qui suit dernier quartier parait un peu plus pr[illegible]l'autre.

La moyenne des deux oscillations

Digitized by Google

Un rapprochement avec la marée luni-solaire s'impose à l'esprit. Les actions de la lune et du soleil s'ajoutent ou se retranchent. Seulement ici c'est le soleil qui est absolument prépondérant; la variation annuelle atteint en moyenne 5'.90, presque exactement 7 fois la variation mensuelle que nous venons de coustater.

La lunaison n'a pas en rèalité 30 jours, mais 29.53. Par ailleurs, l'amplitude de l'oscillation *diurne* se rapporte essentiellement à un nombre *entier* de jours solaires. Si nous considerons néanmoins nos 30 valeurs diurnes comme correspondant à des divisions équidistantes du mois lunaire, nous aurons, en appelant y l'amplitude de l'oscillation et x le temps compté en arcs à partir de la nouvelle lune :

$y = 5'.678 + 0'.04 \cos (x - 69° 52') + 0'.43 \cos (2x - 54° 25')$ formule approchée.

La première ondulation est trop faible pour être considérée comme vraiment sûre. La courbe se réduit donc sensiblement à une sinussoide simple, dont la période complète est une demi-lunaison.

Zi-ka-wei, 25 avril, 1902.

Digitized by Google

NOTE
SUR LA VARIATION SÉCULAIRE DE LA DÉCLINAISON À ZI-KA-WEI (CHINE).

PAR J. DE MOIDREY, S. J.

La variation séculaire de la déclinaison magnétique à Zi-ka-wei présente, in 1878, 1888 et 1898, trois minimums accentués, sûr lesquels nous avions attiré l'attention dans la préface du Bulletin de l'Observatoire pour 1898 (p. iii).

M. Mascart écrivait en 1900: "Il semble que la période des taches solaires se traduit dans les valeurs successives de la variation séculaire." (Traité du magnétisme terrestre, p. 284). Et il citait les observations de M. Moureaux au Parc St. Maur où la déclinaison, qui est occidentale comme ici, diminue plus rapidement les années où les taches sont importantes.

Ce passage de l'éminent auteur nous a engagé à examiner de plus près nos trois minimums. Appelons valeur de D, au 1 janvier ou au 1 juillet de chaque anneé, la moyenne des 12 mois dont cette date occupe le milieu; et variation séculaire, au 1 janvier 1900 par exemple, la différence entre la valeur de cette époque et celle du 1 janvier précédent.

Nous avons soumis à une révision minutieuse toutes les observations de D, faites à Zi-ka-wei depuis 1874, en particulier les déterminations de l'azimut des mires. Ce travail nous a donné le tableau ci-joint pour les valeurs que nous venons de définir. Elles y sont réduites aux dixièmes de minute, mais les calculs ont été faits avec deux décimales au moins.

Au premier aspect de la courbe construite sur ces chiffres, on est tenté de craindre que l'accroissement si rapide de D entre 1874 et 1877, puis sa diminution pendant les 18 mois suivants n'aient été qu'une apparence dûe aux moyens encore assez élémentaires dont disposait alors le directeur de l'observatoire. Cependant nous possédons 13 années (1870 à 1883) d'observations faites à Pékin par le Dr. H. Fritsche.[1] Cette station, comme la nôtre, est située dans l'ovale sino-japonaise de déclinaison occidentale, et presque sur la mêms ligne isogonale. Or la courbe de Pékin affecte précisément la même forme que celle de Zi-ka-wei, avec une allure un peu moins vive. Il parait donc bien probable que nous sommes en présence d'un fait réel.

C'était du reste à peu prés l'époque où la variation changeait de

[1] Ueber die Bestimmung . . . der drei Elemente des Erdmagnetismus . . . , von DR. H. FRITSCHE, p 85, St. Petersbourg, 1893.

Digitized by Google

signe à Colaba[1] et à Batavia,[2] les observatoires les moins éloignés de Chang-hai à cette époque.

Aux dates de 1888 et 1898, nos observations n'ont rien de suspect.

Ainsi la variation, positive d'ordinaire et faible en valeur absolue, s'est trouvée négative à trois reprises différentés qui correspondent assez bien à des minimums d'activité solaire. Trois maximums rappellent, d'une manières moins nette les maximums de 1881, 1884 et 1893.

Le mouvement, occidental ici, oriental à Paris, serait accéléré aux époques de grande activité, retardé ou même changé de signe aux années de calme.

Si on veut préciser, les minimums auraient eu lieu pour nous, en avril-mai 1878, octobre 1887 et juillet-août, 1898 : mais il est peut-être illusoire de pousser si loin des mesures, d elles-mêmes un peu indeterminées.

Remarquons que le minimum de 1898 nous aurait sans donte échappé, si nous n'avions considéré, comme ou le fait d'ordinaire, la variation que pour le 1 juillet.

Remarquons encore en passant que la variation séculaire parait osciller autour d'une moyenne, sensiblement la même pour chaque périodé décennale.

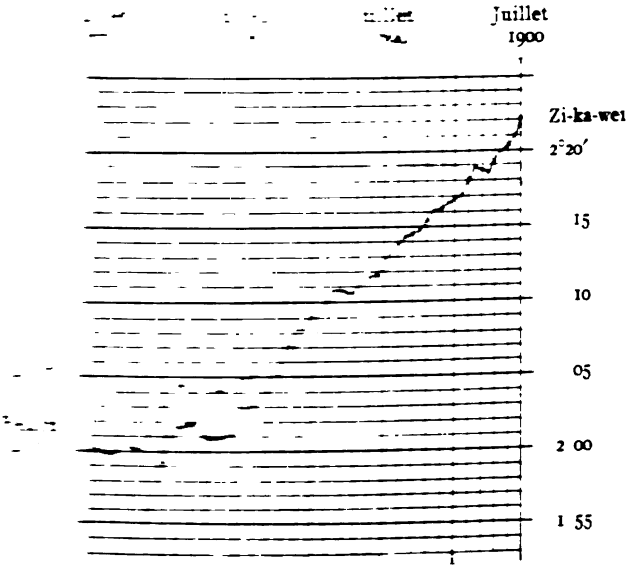
DÉCLINAISON Á ZI-KA-WEI.

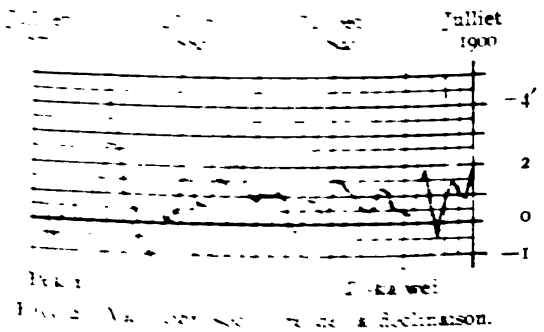
	Moyennes annuelles.		Variation en 1 an.			Moyennes annuelles.		Variation en 1 an.	
	1 Janvier.	1 Juillet.	1 Janvier.	1 Juillet.		1 Janvier.	1 Juillet.	1 Janvier.	1 Juillet.
	° ′	° ′	′	′		° ′	° ′	′	′
1874		1 54.7W			1888	2 10.5W	2 10.8W	−0.2	−0.0
1875	1 57.6W	59.4		+4.7	1889	11.4	11.6	+0.9	+0.8
1876	2 1.0	2 1.6	+3.4	+2.1	1890	11.7	12.5	+0.3	+0.9
1877	1.8	2.0	+0.9	+0.4	1891	13.3	13.9	+1.6	+1.4
1878	1.3	0.8	−0.5	−1.2	1892	14.4	14.6	+1.1	+0.7
1879	0.8	0.9	−0.6	+0.1	1893	14.8	15.4	+0.5	+0.7
1880	1.1	2.2	+0.2	+1.4	1894	16.1	16.4	+1.3	+1.0
1881	2.9	3.2	+1.8	+1.0	1895	16.6	16.9	+0.5	+0.5
1882	3.6	4.3	+0.7	+1.1	1896	17,0	18.0	+0.4	+1.2
1883	5.2	5.8	+1.6	+1.5	1897	18.9	18.6	+1.9	+0.6
1884	7.2	8.1	+2.1	+2.2	1898	18.5	19.3	−0.4	+0.7
1885	8.3	8.9	+1.1	+0.9	1899	20.0	20 3	+1.5	+1.0
1886	9.5	10.0	+1.1	+1.0	1900	2 20.9W	2 22.2W	+0.9	+1.9
1887	2 10.7 W	2 10.8 W	+1.2	+0.8			Moy.	+0.93	+1.09

[1] Le Dr. Chambers donne pour date la 2e moitié de 1879.

[2] Le Dr. Figee (Observations made at the Royal Magnetical and Meteorological Observatory at Batavia. Vol. xxii, part ii, p. xi.) a calculé que ce renversement dans le sens de la variation a du avoir lieu en octobre, 1879, à Batavia.

Digitized by Google





Digitized by Google

BIOGRAPHICAL SKETCH OF GENERAL SIR EDWARD SABINE, F. R. S., K. C. B.[1]

Sir Edward Sabine was the fourth son of Mr. Joseph Sabine, of Tewin, in Hertfordshire. His grandfather, "The Hon. Joseph Sabine, Esquire, General of Foot, Colonel of Her Majesty's Own Royal Regiment of Welsh Fusiliers," as his monument records, afterward serving in all the memorable campaigns of King William and Queen Anne, was rewarded with the Government of Gibraltar, where he died on the 24th of October, 1739. His uncle, Joseph Sabine, a Captain in the Welsh Fusiliers, was killed at the battle of Fontenoy.

Edward Sabine himself was born in Dublin on the 14th of October, 1788, and obtained his first commission at the early age of fifteen years and two months in December, 1803, after a little over ten months as a cadet at Woolwich. He was one of twenty-seven young officers commissioned in that month to meet the rapid augmentation of the regiment, and following twenty-one who were commissioned in September. So urgent was the occasion that the professors and masters were called on to forego their usual vacation to forward the public service.

After a year at Woolwich he proceeded to Gibraltar, and returning in 1807 was appointed to the horse artillery, in which he served at various home stations until the end of 1812. On his promotion in January, 1813, he fell to a company in Canada, and it was on his voyage to Halifax, in the Manchester, Falmouth packet, that he had the first opportunity of showing how gallant a spirit was to be afterwards diverted from the pursuit of military distinction into other channels. The *Manchester*, when eight days out, was attacked by the *Yorktown*, an American privateer, and after a running fight of twenty-four hours, and a close engagement of over an hour, in which Sabine exhibited great gallantry, she had to strike her colors to greatly superior force on the 24th of June, in latitude 47° 10′, longitude 24° 10′. As good fortune would have it, they fell in with the *Maidstone* frigate on Sunday, the 18th of July, and were recaptured; the privateer herself having been taken by the *Maidstone* on the previous day. Instead of being landed prisoners at New York, Sabine and his companions were set on shore at Halifax, his port of destination, and after a week's delay he was sent round to Quebec, where he did military service in the winter of 1813–14. His next service was on the Niagara frontier, where he was favorably mentioned in dispatches; and was one of the officers privileged to wear the word "Niagara" on his dress and appointments, until the "Ubique" superseded all other badges.

On the termination of the war Captain Sabine was ordered home.

[1] Extracted from a "Memoir of General Sir Edward Sabine," by the late General Sir Henry Lefroy, published in the "Proceedings Royal Artillery Institution." No. 5, Vol. XII; Woolwich, 1883; 8°, 16 pp.; a copy of this memoir was kindly loaned to the Editor by Captain E. W. Creak.

Digitized by Google

The early age at which he obtained his first commission makes it very unlikely that he owed his knowledge of Practical Astronomy to the Royal Military Academy. In all probability he acquired it at sea, in days when the sextant was more relied on than it is now for the navigation of a ship; certain it is that his reputation as a skillful observer was such that the President and Council of the Royal Society recommended him, in 1818, for the appointment of astronomer, with an honorarium of 500 pounds, to accompany the expedition sent in search of a northwest passage, under command of John Ross, in that year; and from henceforth, although he had short intervals of military duty, chiefly on the staff in Ireland, down to 1839, his activity was almost exclusively devoted to science.

Sabine was not allowed to be idle long. On the equipment of a second Polar Expedition, under Lieutenant-Commander Edward Parry, in 1819, he was again selected to accompany it. Parry, in the introduction to his Journal, published in 1821, gratefully acknowledges Sabine's labors. Sabine contributed not a little to the cheerfulness and harmony of the expedition by his humorous editorship of the "North Georgia Gazette and Winter Chronicle," a weekly publication, established during its tedious stay at Winter Harbor, when the sun was ninety-six days below the horizon.

Sabine did not accompany Parry on his second voyage; the post of chaplain and astronomer being filled by the Rev. George Fisher. He was himself selected for a far higher office, namely, to conduct a series of experiments for determining the variation of the length of the pendulum vibrating seconds, in different latitudes, with a view to ascertain the true figure of the Earth, a subject which had engaged his attention in the first voyage. He communicated a paper on it to the Royal Society in 1821, which contributed to procure him the honor of the Copley Gold Medal in that year. At that time the ellipticity generally accepted, on the high authority of La Place, was 1/806, and it was with no little surprise that he found on arriving at Sierra Leone that the results he obtained would not accord with that theory. The retardation was several seconds less than he anticipated, proving the ellipticity to be greater; ultimately, the value which he obtained and published in 1825 was 1/288.7, which is almost identical with the final result from all the pendulum experiments made since. Colonel Andrew Clarke, R. E., assigns 1/288.5 in the last edition of the Encyclopædia Britannica (1877). In the pursuit of this investigation Sabine visited St. Thomas, Maranam, Ascension, Sierra Leone, Trinidad, Bahia, Jamaica, in 1821–22; New York, Drontheim, Hammerfest, Greenland, and Spitzbergen, in 1823. No less than five men of the Royal Marines, who had been placed at his disposal by Captain Clavering, R. N., as assistants at Sierra Leone, were carried off by fever during a stay of about five weeks in that pestilential climate.

Digitized by Google

The remarkable account of his experiments, printed in a quarto volume by the Board of Longitude in 1825, must always remain an enduring monument to his scientific merit. It would be impossible in this brief notice to give any adequate idea of the indefatigable industry, the spirit of inquiry, or the range of observation evinced. It appears, indeed, as if he had desired to emulate A. von Humboldt, to whose earlier writings he acknowledges his obligations for awakening in his mind a taste for pursuits, which formed a large portion of his interest and added so greatly to his enjoyment of life. The work was honored by the Lalande Gold Medal of the Institut de France in 1826: and the same year witnessed an event of far greater moment, in his happy union with Miss Elizabeth Juliana Leeves, daughter of William Leeves, of Tortington, thenceforth his inseparable companion, his invaluable and devoted assistant, latterly his vigilant guardian until their union was dissolved by her death in 1879, after fifty-three years of married life. She made herself competent to share in every investigation her husband undertook, and habitually examined and checked his work; suffice it to say that thenceforward his powers were doubled.

Captain Sabine's next service, after the publication of his pendulum experiments, was as a Joint Commissioner, in 1825, with Sir John Herschel, to take part with a Commission, nominated by the French Government, to determine the precise difference of longitude between the observatories of Paris and Greenwich by means of rocket signals. Herschel and M. Largeteau were the observers on the French side of the Channel, at Lignieres; Captain Sabine and Colonel Bonne on the British side, at Fairlight Downs, near Hastings. The difference of longitude thus found was 9m. 21.6s., which was believed to be not more than one-tenth of a second in error, and extremely unlikely to prove erroneous to twice that amount. The accepted difference at the present day of electrical signaling is 9m. 21.0s., a slightly larger error, but the determination was very close.

In 1827 he compared the length of the seconds pendulum and the intensity of the Earth's magnetic force at London and Paris. Having obtained from the Duke of Wellington, then Master-General of the Ordnance, a general leave of absence from military duties as long as he could be usefully employed in scientific pursuits, he became, in 1827, one of the Secretaries of the Royal Society, which office he filled down to 1829. These years were productive of several papers, chiefly on terrestrial magnetism and geodesy.

On the abolition of the Board of Longitude, in 1828, it was determined that three appointments originally given to "three persons well versed in the sciences of mathematics, astronomy, or navigation, as a Resident Committee of the Board," should be continued to three scientific advisers of the Admiralty, each of them receiving one hundred pounds a year; the selection was limited to the Council of the Royal

Digitized by Google

Society, and as the appointment of the Council was virtually in the hands of the President the arrangement was fiercely, and not without apparent reason, denounced as a job. Herschel and Kater, members of the former Committee, declined; Sabine, Faraday, and Young were appointed. This circumstance brought down upon the head of the former a violent personal attack, by Charles Babbage, in a work entitled "Reflections on the Decline of Science in England, and on some of its causes" (1830). Briefly the alleged causes were favoritism and inefficiency in the Council of the Royal Society, exclusion of talents of the highest order—especially mathematical talent—from that body, by the jealousy of mediocrity and absence of adequate encouragement of scientific men from the government of the country. In Sabine's case the point of the attack lay in the alleged *impossible* accuracy of his published observations, It would be as ungracious as useless to revive this forgotten controversy. The late Dr. T. R. Robinson, of Armagh, a most distinguished astronomer, told the present writer, in 1857, that Sabine, being then on the staff in Ireland, smarting under the implied accusation, placed his rough notes in his hands, and entreated him to subject them to the closest scrutiny; feeling much sympathy for him he did so, and found that far from being *sur-humaine*, as Biot declared them, they were rather indifferent observations.[1] The appearance of extreme accuracy was given, as the writer understood, by, in some way, presenting averages, so that they were mistaken for individual results. Certain it is that he retained the firm friendship of Dr. Robinson to the end of his life—a result not consistent with the detection of any inadmissible manipulation of his figures. There is no reason why Sabine should not have been an observer of more than ordinary skill and dexterity, and many reasons why it is probable that he was. His keen eye, light, active, and nervous figure, extreme intelligence and vivacity of temperament, and immense practice, were highly favorable to that result. It was something more than happy chance which made Captain Duperrey, the French navigator, in 1825, fix the longitude of Ascension within 21″ of what Sabine had made it by innumerable lunars in 1822; at the same time there were circumstances which perhaps justified mistrust. Sabine did not condescend to answer the attack, but contented himself by inserting an explanation, in the *Philosophical Magazine* for 1830, on one point which had been particularly laid hold of. It is, of course, not contended that Sir E. Sabine was a mathematician in the sense in which Mr. Babbage understood the term. He often had recourse to real mathematicians, such as Provost Lloyd, of Trinity College, Dublin, or Mr. Archibald Smith, for original investigations, but he was a competent master of applied mathematics, particularly in the class of problems concerned in deducting

[1] M. Biot bore no love to Sabine, who had pointed out in his account of "Experiments to determine the Figure of the Earth" (p. 462), that the theory of terrestrial magnetism, which he had advanced in his "Precis de Physique Experimentale (1821)," could not be reconciled with the facts observed. He had, in fact, found the dip to be only 80°, where the distinguished French philosopher proved that it ought to be 90°.

Digitized by Google

mean results from numerous observations, which require extraordinary care in their solution; and, remembering how early he left the Academy, and how few officers, at all events in those days, were found to extend their mathematics afterward, he deserved much credit for his attainments, without which, indeed, his pendulums might have swung in vain.

Owing to the grave conditions of Ireland in 1830, Captain Sabine was ordered to join his company; he served with it, or occasionally with the Quartermaster-General's Staff, for the ensuing seven years, and acquired the character of being a very "smart officer," but the time was by no means lost to science. He published two pendulum papers in 1830 and one in 1831. In 1834 he commenced, in conjunction with the Rev. Humphrey Lloyd (afterwards Provost of Trinity College) and Captain James Clarke Ross, R. N. (afterwards Sir James Ross, of Antarctic fame), the first systematic magnetic survey ever made by the British Islands. He extended it, single-handed, to Scotland, in 1836, and to England, in conjunction with the same and some additional observers, in the following year. With the exception of the mathematical section of the Irish Report, which was Professor Lloyd's, the Reports—which were published by the British Association—were mainly his; and also a very large share of the observations, more particularly the laborious task of combining them, by equations of condition, to obtain the most probable mean results. About twenty-three years later (1858–61), with unabated interest and still privileged to number Dr. Lloyd among his coadjutors, he undertook, at the request of the General Committee of the British Association, to repeat this survey; and, as before, reduced and reported the results, as far as concerned the elements of dip and force. Captain (afterwards Sir F.) Evans, R. N., Hydrographer of the Admiralty, dealt with the declination.

The year 1836 will ever be memorable in the history of British science, for a letter dated 22d April, addressed to H. R. H. the Duke of Sussex, President of the Royal Society, by Baron Alexander von Humboldt, in which he urged upon the British Government to establish regular magnetic stations in different parts of the British Empire, similar to those which, mainly through his influence and exertions, had already been some years in operation in Northern Asia. This letter was referred to the Astronomer Royal (Airy) and Samuel Hunter Christie for a report, which will be found in the Proceedings of the Royal Society, Vol. III. The pear was now ripe; the Society threw its whole weight into the scale; and probably no busier years were ever known in Somerset House, where the Society had its apartments, than the next three. A Committee on mathematics and physics was appointed in May, 1838, of which Major Sabine[1] and Lieutenant (the late Sir William) Denison, R. E., were members, and towards the end of the year

[1]Captain Sabine received a brevet majority in the usual course of periodical promotion January, 1837, and did duty for a short time at Woolwich.

Digitized by Google

the definitive and official recommendation was made to Her Majesty's Government, already prepared to receive it, to establish magnetic observations, and dispatch a naval expedition to the Southern Hemisphere.

It is needless to say that Major Sabine played an active and conspicuous part in all these negotiations and preparatory arrangements, the first of which, as it immediately concerned the Royal Artillery, will be best seen by the subjoined letter[1] addressed to Lieutenant (later General Sir) Henry Lefroy.

Lieutenant Lefroy's acceptance of this offer was followed by that of Lieutenant (late Lieutenant-General) F. M. Erdley-Wilmot, and Lieutenant (later Major-General) C. J. B. Riddell, and these three officers formed the first Magnetical Staff, under Major Sabine, who was appointed to superintend the whole. Two years later Lieutenant Riddell, being invalided home from Canada, Lieutenant Lefroy was transferred from St. Helena to succeed him, and his place was taken by Lieutenant (later General) W. B. Smythe; about the same time Lieutenant (later Lieutenant-General), C. Younghusband was attached to the Observatory at Toronto; in 1847 Lieutenant H. F. Strange proceeded to St. Helena and in 1844 Lieutenant (later Major-General) H. Clerk was sent to the Cape, whence he sailed the following year to carry out, in the hired bark *Pagado*, Lieutenant H. L. E. Moore, R. N., in command, an extensive survey of parts of the Antarctic Ocean not visited by the *Erebus* and *Terror*, under Sir James Ross, of which he gave an account in the Philosophical Transactions of 1846. Thus it will be seen that, thanks

1 April 10, 1839.

My Dear Sir:

The inclosed report and its subjoined letter will make you acquainted with the particulars of the scheme of magnetic research which has been fully acceded to by the Government.

You will perceive it consists of two branches: a naval expedition and fixed observatories at certain stations on land. The naval branch is, of course, undertaken by the Admiralty and the ships, or one at least, is this day commissioned. It is the intention of Lord Melbourne that the fixed observatories should be carried into execution by the Ordnance Department, and Sir Hussey Vivian is to be acquainted with the intention to-day. The observatories are to be three in number: Canada, St. Helena and the Cape of Good Hope; others are to be established by the East India Company, and other nations are to be invited to co-operate. The duration of the observatories is not to exceed *three* years, and it is proposed that each should be under the direction of an officer of the engineers or artillery with three non-commissioned officers of his choosing. I know not how such employment might be suitable to your wishes, but from conversation I have had with Sir A. Dickson I think it mos tprobable that he will look to you as the first person whose wishes he will ascertain. I therefore write you this *private* note, to give you a little more time than you might otherwise have for considering the subject, and to offer you any further explanation you may desire in considering it. The Dublin Observatory (Professor Lloyd's) will be the model on which the fixed observatories will work. The Officers who undertake their charge will have to be instructed there, and you may be quite sure that there will be no part of the duty of which you will not be able to make yourself fully master.

(Signed) Edward Sabine.

Digitized by Google

to the strong position attained by his own great abilities, the claim of the Royal Artillery to its reputation as a scientific branch of the army, which he had sustained indeed almost alone for many years, was fortified by the appointment of no less than seven junior officers from its ranks, for a scientific purpose, all but one of whom became eventually Fellows of the Royal Society. It would be ungrateful to omit to record how zealously and admirably they were served by the intelligent non-commissioned officers of Artillery, selected as their assistant observers.

Major Sabine was appointed general secretary to the British Association in 1839, a laborious office, which he continued to hold to 1858. In 1846 he became foreign secretary to the Royal Society and in 1850 vice-president and treasurer, having received the Royal Medal the previous year. The high honor of being elected president of the British Association, in succession to the Astronomer Royal, fell to his lot in 1852; and the yet higher honor of being elected president of the Royal Society in 1861; he filled this chair till 1871; he was a member of the principal learned societies and scientific bodies in Europe and America and was made a K. C. B. in 1869. He received also most of the honors it is in the power of English universities to bestow.

Although it is impossible in the compass of a brief sketch to give even the most concise summary of the scientific results which flowed from his inexhaustible industry, aided by a clerical establishment maintained by Government for twenty years (1841–1861) at his exclusive disposal;[1] this memoir may be reasonably expected to devote some space to that portion of them which from the personnel employed, may be represented as a service rendered to science by the Royal Artillery.

The observatories began their work in 1840. The first publication was a quarto volume of observations on days of unusual magnetic disturbances, published in 1843, which was followed by a second, on the same subject, in 1851. The introduction to this latter was by Captain Younghusband, then Lieutenant-Colonel Sabine's assistant. Next followed the volumes of regular magnetical and meteorological observations, eleven in number—observations made every two hours in 1840–41, and every hour after that date. They form but a fractional part of the enormous mass of the material of the same description made available to science in the course of the succeeding twenty years; but, from the uniformity of the plan pursued and the wide distribution of the stations over the globe, must always take a prominent place among the international results. Each of these volumes is preceded by a discussion of its contents by Lieutenant-Colonel Sabine, the general editor. The several directors of the observatories had no part allótted to them beyond responsibility for the routine of their establishments, and the arithmetical accu-

[1]For thirteen years (1841–1854) he had the assistance of an officer—first Lieutenant Riddell, then Lieutenant Younghusband—and four or five military clerks: from 1854 to 1861 of a civil chief assistant (previously one of these non-commissioned officers) and four military clerks.

Digitized by Google

racy of the returns of observations transmitted monthly to Woolwich. A great inducement was thus withheld from them, to study the subjects with which they dealt, in their higher or general aspects and their responsibility was lowered. The occasion is never likely to repeat itself; but if it should do so, a greatly modified system should undoubtedly be followed.

General Sabine's introductions to these bulky volumes amount to nearly eight hundred (quarto) pages, and treat in turn of every subject presented for investigation. The periodical laws governing the observed changes of each of the magnetic elements, and the like for those of meteorology. Their connection with solar physics, the influence of the moon upon them; the laws governing the irregular fluctuations of each element; secular changes; all of these unequal in different places, and some of them, if not absolutely his discoveries, for the first time worked out fully by him.[1] The activity of mind, and the indefatigable industry evinced by him, the laborious services of his clerical assistants, frequently acknowledged, all come out the more strongly the more these introductions are studied. Let us, for example, suppose the inquiry to be, "Whether the daily passage of the moon across the meridian produces any perceptible effect upon the magnetism of the Earth?" the method pursued was this:

Having before him the sheets containing the observations for a whole month, arranged in twenty-four parallel columns for the several hours, and the means truly taken, about 624 readings for each element, the computer proceeded to take the difference between each individual observation and the mean at the same hour, for the month; all which exceeded a certain arbitrary limit (four scale divisions), and were regarded as *disturbed*, by the operation of causes unconnected with the moon, were then set aside or lined out, and the observation nearest to the hour of the moon's meridian passage on each day, being marked, all the remainders were rewritten out in twenty-four columns, corresponding to the intervals of time before and after the passage. This having been done in the case of the declination at Toronto alone for 45,000 observations, it is ultimately ascertained that the north end of the magnet at that station is deflected to the amount of 18.″95 when the moon is on the upper meridian, and to the amount of 19.″38 when she is on the lower meridian, both to the *east;* also to the amount of 20.″21 six hours before her meridian passage, and 18.″14 six hours after her meridian passage, both to the *west.* The inclination and the force exhibit corresponding effects, the former three hours later, the latter also three hours later in the post-meridian period, but four hours later in the ante-meridian period.

[1]Thus the lunar effect on the barometer was discovered at St. Helena, by Lieutenant Lefroy in 1842 (see Proceedings Royal Society, 1842, p. 395). The lunar effect on the magnetic declination by M. Kiel, at Prague, in 1841, and on the horizontal force by Mr. John Allen Brown, at Makerstoun, in 1844. In both cases the investigation was greatly extended, but not originated by Sabine.

Digitized by Google

By a similar method of investigation, Lieutenant-Colonel Sabine was able to make an announcement, which was received with much scientific interest in 1852, of a remarkable coincidence between "the periodical inequality by which the magnetical variations, referable to solar influence, are affected, and the periodical inequality which has been discovered by M. Schwabe (in 1838) to exist in the frequency and magnitude of the solar spots."

As we have already observed, the full value of these laborious computations remain to be realized when the nature and extent of the connection between solar and terrestrial physics, and the origin of the Earth's magnetical conditions are better understood; they are in the meantime important contributions towards that result.

The dates of these publications were:

Toronto,	to 1842, Vol. I,	1845
Toronto,	to 1845, Vol. II,	1853
Toronto,	to 1848, Vol. III,	1857
St. Helena,	to 1843, Vol. I,	1847
St. Helena,	to 1849, Vol. II,	1860
Cape of Good Hope, magnetic,	to 1846, Vol. I,	1851
Cape of Good Hope, meteorological,	to 1846, Vol. II,	1880
Hobarton, Tasmania,[1]	to 1842, Vol. I,	1850
Hobarton, Tasmania,	to 1842, Vol. II,	1852
Hobarton, Tasmania,	to 1842, Vol. III,	1853

It has been mentioned that the East India Company took a large share in the International inquiry. They established an observatory at Simla, under Lieutenant (now Major-General) Theophilus Boileau, Bengal Engineers; one under Lieutenant Ludlow, Madras Engineers, at Madras; and another under Lieutenant Elliott, also Madras Engineers, at Singapore. Major Sabine had nothing to do with these after the first steps, and their history was disastrous. The original records at Simla were all destroyed by fire in 1858, the cases in which they had been packed for transmission to England, by Colonel Boileau, R. E., on his retirement in 1857, having been transferred during the mutiny from the safe depository, in which he had placed them, into a storeroom, which took or was set on fire. He ultimately published the meteorological observations from copies in England in 1872; those of the other two observatories were printed at the American Mission Press, Madras.

From these official publications we pass to magnetic surveys. Sir E. Sabine lived to complete, in fifteen "Contributions" to the Philosophical Transactions, a gigantic work undertaken by him, namely, a survey of the general distribution of magnetism over the globe at this epoch. Several of these appeared after he had lost the aid of his establishment of clerks, the last in 1876. In these are to be found every

[1] The observatory at Hobarton was founded by Sir James Ross, R. N., and conducted by officers of the Royal Navy under Lieutenant Kay, R. N.

Digitized by Google

observation of any authority, taken by sea or land, since 1835, or thereabouts, arranged in zones of 5° of latitude, and taken in the order of longitude around the globe. All the results of Arctic and Antarctic voyages, special expeditions, such as (to name officers of artillery only) those of Lefroy, Clerk, Blakiston, Haig, and everything that he could glean from Russian, German, and American and other foreign sources, much of which is not accessible in any other form were given. These results were accompanied by admirable maps prepared for him in the Hydrographical Department of the Admiralty, under the supervision of Captain (later Sir) Frederick Evans, R. N. It may be safely said that had Sir E. Sabine done nothing but collect, compile, and discuss this vast mass of material, he would have rendered a service to science, which would make his name live as long as Halley's—but it forms but a part of his life's labor. Communications to the Royal Society and the Philosophical Magazine on some subject of the moment were always pouring from his pen. It has not been attempted to enumerate them. His addresses to the British Association and the Royal Society, as President, also must not be forgotten. The Royal Society Catalogue of 1870 gives the titles of ninety of his papers, and several appeared after that date; and after his eightieth year, more particularly his "Contributions" to magnetism, Nos. XIII, XIV, and XV. It was not until 1876 that age and infirmities brought his long labor to a close. His latter years, which terminated on 26th June, 1883, at the age of ninety-four years, eight months, were clouded by that eclipse of the faculties which so often attends the closing scenes of a life prolonged far beyond the ordinary limits of human strength; and his remains were laid beside those of his beloved wife at Tewin on the 30th, in the presence of his nearest relations, together with representatives of the Royal Society and the officers who had served under him.

Sir Edward Sabine's likeness, in the messroom at Woolwich, taken when he was past eighty years of age, although an excellent work of art, does but imperfect justice to him; there is a much better one at the apartments of the Royal Society.[1] He has left no descendants, but the Sabine family survives in his nephew, Admiral Sir Thomas Sabine Pasley, R. N. Here must terminate this brief sketch of the life and labors of one of the most remarkable men whom the English Artillery has produced.

[1] The reproduction in this Journal is from the latest photograph of the Royal Society picture, taken by Captain Sir W. Abney, and a copy of which was forwarded to the Editor by Captain Creak, with the special permission of the Council of the Royal Society. The plate shows, in the right-hand corner, the mace which is always laid on the table before the president during the meeting of the Royal Society.—ED.

Digitized by Google

MAGNETIC DEFLECTION OF LONG STEEL WIRE PLUMB LINES.

W. HALLOCK.

The Portage Lake *Mining Gazette*, in its issue of October 10, 1901, gave a very complete and interesting account of some recent operations in the very deep shaft of the Tamarack Mining Company, on Lake Superior. It became necessary to plumb down two points to a depth of 4,250 feet, and for this purpose the plumb lines were made of No. 24 piano wire carrying a 50-pound iron weight. At first the two lines were 16.33 ft. apart at the top, but were afterward moved to a distance of 17.58 ft. It was thought that possibly these plumb lines, over 4,000 feet in length, might show the convergence of the Earth's radii, or possibly the Newtonian attraction between the two 50-pound masses of iron. On measuring the distance apart at the bottom it was found that in the first case they were .09 ft. and in the second case .07 ft. farther apart at the bottom than at the top. This, being contrary to expectation, called forth various suggestions as to its explanation. The one most persistently maintained was that the displacement was due to an attraction between the mass of iron and the nearer wall of the shaft; but this could not be the case—first, because the mass of iron is in a practically inclosed space, and would, consequently, experience no attraction; and, secondly, if we consider the suggested explanation we find that it would suffice to move the plumb-bob only about .001 ft. Any one who has worked around oil wells or gas wells knows to what extent the tools and the casings become magnetized from their being held in a vertical position, and while there undergoing frequent jarring. This magnetization, due to the vertical component of the Earth's magnetism, led me to think that it might be possible that the two steel wires in the plumb lines became magnetized with north poles at the bottom, and these two north poles repelling each other would account for the observation. When it is remembered that the vertical component in these latitudes is at least three or four times as great as the horizontal component, it need not be surprising that these masses of iron became decidedly magnetic. If, however, we assume a field—for example, of .6—a simple calculation will show that this would not produce a sufficient magnetization to account for the repulsion in question, but if the inequalities in the wires should result in the form of consecutive poles along their length, then the combined effect of all these might be sufficient to give the deflection observed.

To test the above as to the magnetic cause of the deflection, I made a series of observations in the research shaft at Columbia University.

Digitized by Google

A bar was mounted so that it could be rotated in a horizontal plane, about its middle point, and at one end a plumb line was placed, which consisted of a fine copper wire carrying a non-magnetic bob. At the other end of the bar was another plumb line, consisting of a soft iron wire, about .02 inch in diameter, with a similar bob. These plumb lines were 75 feet long, and were about 4 inches apart, and their plane coincided approximately with the magnetic meridian. Observations showed that the bobs were about 1-75 inch closer together when the iron was south of the copper than when it was north. In other words, the iron plumb line was pulled about 1-150 inch toward the north by the action of the horizontal component of the Earth's field upon the iron wire.

The experiment was varied by taking two lines of the soft iron wire, about 1 inch apart, and measuring their distance apart at the top and bottom. Under these conditions the mutual repulsion gave a deflection of the same order as the pull of the Earth's field.

Thus we have undoubtedly an effect upon the lines due to induced magnetism, but again too large to be due to a simple pole at the ends. It was consequently desirable to investigate whether there were poles along the line, and with a very small compass they were investigated along their whole length, with the following result:

Position on wire	South wire	North wire	Effect
Top	Strong south	Strong south	Strong repulsion
5 ft.	Weak south	Weak south	Weak repulsion
10 "	South	South	Repulsion
15 "	Weak north	South	Weak attraction
20 "	North	North	Repulsion
25 "	North	Neutral	Neutral
30 "	Weak south	Neutral	Neutral
35 "	Weak north	Neutral	Neutral
40 "	North	North	Repulsion
45 "	South	South	Repulsion
50 " Bot.	Strong north	Strong north	Strong repulsion

In the plumb lines the upper 25 ft. above the point referred to as the "top" was of fine copper wire; the above table is for the 50 ft. of iron wire forming the lower two-thirds of each plumb line.

The conclusion is evident. Iron or steel wire ought not to be used for plumb lines where accuracy is needed, as they are deflected by the Earth's field as well as by each other. Probably phosphor-bronze would prove most available where great tensile strength is needed.

FAYERWEATHER PHYSICAL LABORATORY, COLUMBIA UNIVERSITY.

Digitized by Google

DIVERGENCE OF LONG PLUMB-LINES AT THE TAMARACK MINE.[1]

F. W. McNAIR.

In September last two very long plumb-lines were hung in No. 5 shaft of the Tamarack Mine at Calumet, Michigan. They were 4,250 ft. in length, being longer than in any previously recorded instance. They were of No. 24 piano wire and the bobs were of cast iron, weighing fifty pounds each. Great care was taken that there should be no interference from projecting objects nor from dropping water, of which, indeed, there is not a great deal in the shaft. Measurements between the lines taken at surface and at their lower extremities showed a divergence to the amount of 0.11 ft. A divergence of 0.07 ft. remained after the western wire had been moved about 1.25 ft. further west to insure its freedom from obstacles. Thinking that the air pipes which run down the western end of the shaft might, through magnetic action on the bob nearest them, be causing this divergence, I advised the use of lead bobs in a plumbing of No. 2 shaft, which took place a little later. Although the length of the lines in No. 2 was about 120 ft. less than when they hung in No. 5, and although the lead bobs were used, there was yet a divergence of 0.10 ft.

The publication about this time in the Houghton *Daily Mining Gazette* of the fact that a divergence had been observed attracted wide attention, and brought forth many attempts to explain its existence. Those immediately cognizant of the conditions had no satisfactory theory to offer. One of the explanations was that the divergence was due to the greater attraction of the material at the end of the shaft for the bob hanging nearest it. It is remarkable how many engineers and other trained persons held to this theory. There seems to exist a general lack of appreciation of the forces of gravitation, except in the single instance of the force between the earth and objects upon it. It is of course true that the attractions on either bob towards the ends of the shafts are different, the stronger being toward the end nearest to which it hangs. Furthermore, these differences of attraction tend to diverge the lines. Their amounts, however, are in this case so insignificant as to put them quite out of consideration in attempting to explain the divergence. Their sum is only a few hundredths of a grain, and the consequent divergence only about 0.001 ft.

Professor Hallock, of Columbia University, suggested the theory of repulsion between like poles at the lower extremities of the wire, but afterwards modified this to include repulsion between like consequent poles distributed along the wires.

[1] Reprinted from "Science," VOL. XV, No. 390, June 20, 1902.

Digitized by Google

Permission having been granted me to carry on further experiments in No. 4 shaft of the Tamarack Mine, there were hung in this shaft bronze wires No. 20 B. & S. gauge, carrying 60-pound lead bobs. These lines were approximately 15ft. apart and 4,440 ft. in length. By a simple system of triangulation the distance between the mean positions of their lower extremities was determined, while the distance between them at surface was directly measured. It is thought that these distances were compared with an error not greater than 0.003 ft. A small convergence of 0.28 ft. was observed. The steel wires were then hung in the same position at the top, and the positions at the bottom observed, both with lead and with iron bobs. The bronze wires were hung a second time, but somewhat nearer together, and were found practically parallel. The steel lines showed a slight convergence. Subsequently the bronze wires with lead bobs were hung in No. 5 shaft in the same position, as nearly as might be, as was occupied by the steel wires in September. The divergence was greater, amounting this time to 0.141 ft. The results are exhibited in the following table:

Date. 1902.	Shaft.	Wires.	Bobs.	Distances in feet.		Convergence—. Divergence+.
				Surface.	Lower Extremities.	
Jan. 3	No. 4	Bronze.	Lead.	15.089	15.061	—0.028
" 6	" 4	Steel.	Lead.	15.089	15.074	—0.015
" 6	" 4	Steel.	Iron.	15.089	15.062	—0.027
" 9	" 4	Bronze.	Lead.	14.607	14.611	+0.004
" 16	" 5	Bronze.	Lead.	16.709	16.850	+0.141

The data shown in the table seemed to afford ample experimental proof that neither gravitation nor magnetism could account for the divergence originally observed. Further, it seemed that the results pointed clearly to the currents of air in the shafts as the disturbing cause.

Until No. 5 shaft is connected with other portions of the mine its ventilation is accomplished by dividing it into two parts by means of a tight casing which sets off one compartment and the ladder-way, at the western end of the shaft, to serve as an air chimney for the up-cast draft. At the time of the September and January plumbings there existed at different levels a number of openings in this casing. The west wire hung in the air chimney, and these openings permitted a rush of air from the down-cast side into the up-cast portion, the effect of which would be to move the west wire toward the west and thus produce a divergence. To make the proof as complete as possible it was decided to hang the bronze wires once more in this shaft, but to hang the west one

Digitized by Google

in the compartment next the air chimney, rather than in it. It seemed that if both wires were hung in the down-cast portion the divergence ought to disappear. Moreover, communication between the air chimney and the down cast portion was carefully stopped off as far down as the extent of the wires, and, to further prevent circulation, the shaft was covered at the top as soon as the wires were in position. Since a considerable difference in temperature exists between the bottom of the shaft and the surface, it was not possible to stop all circulation. There remained a considerable convection circulation whose down-cast portion was concentrated along the casing above referred to. The measurements between the wires were at surface 11.944 ft., at bottom 11.962 ft., showing a divergence of 0.018 ft. This divergence was easily accounted for by the convection current just described.

The difference between the divergence of the steel wires hung in this shaft in September, and of the bronze ones in January is explained by the fact that the circulation in the warmer weather of September was much less vigorous than in January and, further, that the steel wires afforded the smaller surface to be acted upon.

The question of air currents had been considered early in the experiments. That they could account for the divergence was very slowly admitted by the observers, inasmuch as it was difficult to believe that currents of air could be of the steadiness, in both volume and direction, which would be necessary to permit the constancy which was observed in the mean positions of the lines. The mean positions were observed on scales, placed close to the wire. Most of the time scales divided into sixteenth inches were used. For hours at a time the variations of the mean position of a wire would not exceed three or four tenths of a scale division. The mean position was determined by drawing the wire aside and allowing it to vibrate, as in determining the resting point of a balance by the method of vibrations.

The responsibility of the air currents once admitted, it was found by studying the conditions in No. 2 shaft that the divergence there observed could be satisfactorily explained. The shaft is down-cast and the air leaves it at the west end to reach the mine. The small convergence observed in No. 4 shaft can likewise be accounted for by the swirl of the currents as they enter this shaft, which is up-cast. The contour of the walls of the plats is such that the currents of air hugging the outside of the curve as they enter the shaft will have a tendency from the west wall toward the center. Moreover, it appears that this tendency will be stronger close to the wall than a little distance away. When therefore on the 9th of January, the west wire was moved eastward, lessening the distance between the lines, the wires hung more nearly parallel than when this wire was close to the wall of the shaft.

It seems therefore that a very simple cause was at the bottom of the divergence. The remarkable fact is that the currents of air should be so constant in their action. When, however, the great depth of the shafts is considered, also the constancy for considerable periods of time of the temperatures which may influence these currents, it seems reasonable that this steadiness should exist.

HOUGHTON, MICH. MICHIGAN COLLEGE OF MINES.

Digitized by Google

NOTES

16. *The International Meteorological Committee* will have its next meeting during the second week of September, 1903, in the city where the British Association for the Advancement of Science will meet.

17. *Proposed Magnetic Work of the United States Coast and Geodetic Survey, July 1, 1902–June 30, 1903:*

a. Magnetic Survey Work. The determination of the three magnetic elements at 400–500 stations distributed principally in Virginia, New Jersey, Pennsylvania, Ohio, Kansas, Nebraska, Texas, Arkansas, and Florida.

b. Magnetic Observatory Work. The continuous operation of the four magnetic observatories situated at Cheltenham, Maryland; Baldwin, Kansas; Sitka, Alaska; and near Honolulu, Hawaiian Islands; also the selection of sites and preparations of plans of an observatory in Porto Rico or vicinity, and another in the extreme western part of the United States.

c. Ocean Survey Work. The inauguration of magnetic work on board ship in connection with regular trips of vessels engaged in coast survey work.

d. Special investigations conducted either at the observatories (e. g. international work) or at educational institutions by persons available as "associate magnetic observers."

e. At the office at Washington a special effort will be made to bring all computations of field work performed and investigations conducted since July 1, 1899, up to date and to prepare results for publication.

18. *Progress of Magnetic Work at the Melbourne Observatory.* From Mr. Baracchi's report[1] to the Board of Visitors for the period covering April 1, 1900, to March 31, 1901, the following is extracted:

"The magnetographs have been in continuous use for registering, photographically, the variation in the magnetic elements; but owing to abnormal diurnal changes of the gas pressure and defects in the gas service at the magnet-house, the lights in use with these instruments failed at irregular times during the winter months of last year, and many interruptions were thus caused in the records, amounting in the aggregate to 353 hours. After trying various experiments with gas regulators in September and October we succeeded in obtaining steadiness of pressure throughout the twenty-four hours of the day, and the lights have been very good and constant ever since.

"The measurement of magnetic curves and reduction of records accumulated since 1868 have been steadily carried on by the temporary computers specially engaged for this work. The number of one-day curves measured in the year ending 31st March, 1901, is 9,143, comprising the years 1868, 1881, 1885, 1886, 1887, 1888, 1889, and 1891."

Also from his report, for the period, April 1, 1901, to March 31, 1902, the following statement is taken:

"The photographic registration of the three magnetic elements, declination, horizontal, and vertical components, has been continued as in former years.

[1] Melbourne Observatory. Thirty-fifth Report of the Board of Visitors to the Observatory; together with the Report of the Government Astronomer for the period from April 1, 1900, to March 31, 1901. Melbourne, 1901. 10 pp., 21 x 33 cm. Also Thirty-sixth Report for period April 1, 1901, to March 31, 1902, Melbourne, 1902.

Digitized by Google

"I regret to say, however, that serious interruptions occurred, mostly in the last winter months, through various causes, the principal ones being corrosion and other defects in the gas pipes, which necessitated general repairs and renewal in some parts, other repairs to gas fittings, mounting of new burners with incandescent mantels, and alterations to the gear of the driving clock. The aggregate interruptions extended over 11¼ days.

"A scheme of co-operation in magnetic work was laid out by the Anglo-German Committee appointed by the International Geographical Congress of Berlin, in 1899, in connection with Antarctic expeditions, to extend over the years 1902 and 1903, in which the Melbourne Observatory was expected to take its share.

"The programme of the work consists in making complete determinations of the value of the magnetic elements on certain specified days, namely, 1st and 15th of each month, and observing the variations of these elements during one specified hour on each term-day by readings taken at intervals of twenty seconds, or by ordinates measured at the same intervals on photographic traces.

"Observations in accordance with this programme have been carried on here regularly since last December.

"In order to obtain sufficiently minute detail of variations during the hour-term, it was required to provide means in our magnetographs for increasing the speed of the revolving drums at the specified hours from one revolution per day, which is the ordinary movement, to one revolution in two hours.

"This was done by introducing extra gear in the driving clock, by which we are now enabled to use the slow or quick motion when required, without interruption in the records.

"Incandescent mantels were also fixed to the gas burners, as above mentioned, in order to obtain sufficiently dark traces during the hour-term when the drums revolve at the quicker rate.

"Good progress has been made in the measurement of the magnetograph curves and reduction of all magnetic observations of the past 30 years.

"The number of day curves measured is as follows:—

"Declination	2,811
"Horizontal component	2,855
"Vertical component	2,962
"Total	8,628

"The total number measured to 31st March, 1902, is 21,877, which covers the periods 1868–76 and 1881–91, the remainder being curves for days on which absolute observations were made between the years 1872 and 1900."

Mr. Baracchi also writes "that the measurement of the 30 years' photographic records at Melbourne Observatory has been going on and is now far advanced. I hope to clear up all arrears during the next two years or so."

19. *Personalia. Professor Dr. Adolf Schmidt*, of Gotha, has been appointed director of the Potsdam Magnetic Observatory in succession to the late lamented Professor Eschenhagen. He will take charge on October 1st.

Professor Rücker was among those upon whom the honor of knighthood was conferred at the coronation of King Edward VII.

Dr. Wilhelm Trabert has been appointed to a full professorship of cosmical physics at the University of Innsbruck.

Mr. Edward R. Smart, in charge of trigonometric work in the Island of Trinidad, spent some time at the Coast and Geodetic Survey familiarizing himself with the instruments and methods in use in the geodetic and magnetic work. *Father Edmond Goetz, S. J.*, likewise familiarized himself at the Coast and Geodetic Survey with magnetic instruments and methods, preparatory to work he contemplates undertaking, starting out at Bulwayo, Rhodesia.

Dr. C. H. Hind, of Groningen, will hereafter have charge of the meteorological institute at de Bilt, near Utrecht, whereas Dr. Snellen will have exclusive charge of the magnetic observatory.

Digitized by Google

ABSTRACTS AND REVIEWS

THE ANTARCTIC MANUAL.[1]

[1] For the [British] Antarctic Expedition of 1901. Edited by George Murray with a preface by Sir Clements R. Markham. Presented to the expedition and issued by the Royal Geographical Society. London, 1901, 8°, 586 pages and three maps of the Antarctic regions.

This Manual dedicated to Sir Joseph Dalton Hooker, the last surviving member of the expedition of the *Erebus* and *Terror* into the Antarctic, and edited by Mr. George Murray, F. R. S., Keeper of Botany, British Museum and Director of the Civilian Scientific Staff of the expedition, consists of instructions and memoirs containing information prepared by eminent scientists for the use of the British Antarctic Expedition.

The contents are as follows:

Ice Nomenclature—Sir Clements R. Markham and Hugh Robert Mill
Astronomical Data—Superintendent of the Nautical Almanac
Tidal Observations—G. H. Darwin
Pendulum Observations—R. T. Glazebrook
Terrestrial Magnetism—Captain E. W. Creak
Antarctic Climate—Robert H. Scott, W. S. Bruce, Dr. Supan, Louis Bernacchi
Wave Observing—Commander Wilson-Barker
The Aurora—Professor Arthur Schuster
Atmospheric Electricity—Lord Kelvin
Chemical and Physical Notes—J. Y. Buchanan
Geology—W. T. Blanford
Volcanoes and Volcanic Action—J. W. Judd
Ice Observations—Professor J. W. Gregory, Professor T. G. Bonney
Instructions for Collecting Rocks and Minerals—L. Fletcher
Zoology—R. Lydecker, G. E. H. Barrett-Hamilton, Howard Saunders, G. A. Boulenger, Arthur E. Shipley and Professor D'Arcy Wentworth Thompson
Botany—George Murray
Arctic Sledge-traveling—Admiral Sir Leopold M'Clintock
Geography—Charles Darwin-Charles Wilkes, M. J. Dumont-d'Urville, Henryk Arctowski, Louis Bernacchi, John Biscoe, John Balleny, John Balleny's Mate
Antarctic Bibliography—Hugh Robert Mill
Maps—Sheets 1, 2, 3

Digitized by Google

RELATION BETWEEN SEISMIC AND MAGNETIC DISTURBANCES IN JAPAN.[1]

BY N. YAMASAKI.

[Extract from p. 12.]

"Finally there is a remarkable phenomenon deserving mention, viz.: that a few days before an earthquake, magnetic disturbances occur. This, it was able to show, occurred during the past ten years with every violent earthquake shock in Japan. (See *Omori* and *Imamura*, on the velocity of progression of earthquake waves, in Trans. of Seismological Committee, vols. XXI and XXXII; also *Cfr. Homma*, Earthquakes and Terrestrial Magnetism, Trans. Seis. Comm., vol. XXXII, p. 131; and *Yamasaki*, the Great Earthquake in Northern Honshu on Aug. 31, 1896, Petermann's Mittheilungen, 1900, Heft. xi, p. 1.)

"In general, the magnetic disturbance was at first greater at those stations nearest the epicenter of the earthquake, and was weaker at the stations farthest away. But rarely was it observed that magnetic disturbances did not precede earthquakes. It would seem therefore, that there exists some relationship between the two phenomena, and that a further investigation will be a valuable contribution to geophysics.

"The Seismological Committee has already established eight magnetic observatories, built with especial care and equipped with the Mascart magnetographs. When the relationships have been subjected to a more exhaustive investigation, we may possibly be able to found a system of earthquake prediction."

PROTECTION OF SHIPS' COMPASSES FROM ELECTRIC CURRENTS.

Rear Admiral Bradford, chief of the U. S. Bureau of Equipment, has received an interesting letter from Lieutenant-Commander F. M. Bostwick, navigator of the *Oregon*, in which he describes the effect on the standard compass of a "ground" in the bridge electric circuit. While the *Oregon* was steaming up the China Coast on course N. E. by N., the navigator reports that it suddenly became necessary to change the course about a point to the eastward by bridge and steering compasses, to make the allotted course by standard. Upon investigation it was found that the trouble lay with the standard compass. A time azimuth taken showed the deviation of the standard compass to be 10° and 4-100′ E., the tabulated deviation being 1° and 4-100′. Upon inquiry it was found that the bridge circuit had just been turned on, and later a "ground" was discovered. Experiments showed conclusively that the fault was due to this "ground." In order that this trouble may be avoided in the future, the Secretary of the Navy has authorized the chief of the Bureau of Construction and Repair to inform the commandants of the navy yards and the superintending naval constructors that hereafter the platforms for carrying the standard compass should, whenever practicable, be insulated from the structure of the ship by three-eighths of an inch of hard rubber fiber, and that the bolts securing platform stanchions to the structure should also be insulated by bushings and washers of the same material; also that all horizontal railings within 12 feet of the compass should be made either of wood or manilla hemp rope.—*Electrical World and Engineer*, August 10, 1901.

EARTH-CURRENT OBSERVATIONS IN THE GERMAN TELEGRAPH SYSTEM.[1]

The origin of these important observations dates back to 1881, when a committee was called together by Werner Siemens, to study the phenomena of earth-currents. Through their efforts, two underground cables were provided by the Imperial Telegraph System, one running in an easterly direction from Berlin to Thorn, 262 km., the other nearly due south from Berlin to Dresden,

[1] Erdbebenforschung in Japan. Vortrag gehalten am Geographenabend an der Wiener Universität. Repr. from "Erdbebenwarte," 12 pp.; 1 plate. Laibach, 1901.

Digitized by Google

120 km. The present work deals chiefly with the continuous observations of earth-currents from these two lines, from 1884 to 1888. The Prussian Academy of Sciences assisted, in part, in the maintenance of the observations.

The assumption is made at the start that the observed currents are due to potential differences between the ends of the lines; that is, they are derived from currents that flow in closed circuits within the Earth, parallel to its surface. Of course *vertical* differences of potential have to be left out of consideration.

The attempt to express the intensities in the two lines by trigonometrical formulæ according to Gauss, using the latitude and longitude as variables, leads to equations whose constants are too difficult to be determined. Assuming the validity of Ohm's law, however, the intensity of the earth-current components in the two directions may be given by the equations

$$J = A\frac{W}{L}i, \quad J' = A\frac{W'}{L'}i',$$

where A is a constant, and W, W', are the resistances, L, L' the lengths, and i, i' the observed current-strength in the two lines respectively.

We thus obtain for the total earth-current,

$$E = A\sqrt{\frac{W^2}{L^2}i^2 + \frac{W'^2}{L'^2}i'^2},$$

The value of the constants was computed for each of the two lines. The results are only relative, however, as no reductions to absolute units were made.

The most characteristic feature of earth-current variations is their dependence upon the position and condition of the Sun. The diurnal and annual variations are especially marked. In view of this, the attempt is made to modify the trigonometrical representation in such a way as to use instead of the latitude, the angle with the Sun's declination, and for the longitude, the local time or the right ascension of the Sun. The results indicate, however, as was to be expected, that this is not sufficient, but that other factors have to be considered. In general there can be distinguished a constant component of the current, due to terrestrial and local conditions, and a variable component, depending chiefly upon the Sun. The four years of observations were not enough to make the derivation of accurate formulæ possible. As approximations, however, expressions for the components in the two directions were derived, as functions of the local time and its multiples from which the diurnal variation is made evident.

The self-recording instruments were of two different types. In the Berlin-Dresden line a Siemen's "Russschreiber" was used, in the other line a mirror-galvanometer reflected a beam of light on to photographic paper. The sensitiveness of both instruments was frequently determined, and though the results were not reduced to absolute measure, still it is always possible to get accurate relative values between the two lines.

The magnetic records, which, as the title indicates, formed an essential part of the work, were obtained chiefly from the observatories at Wilhelmshafen and Vienna, but to a lesser extent also from the observations during the international polar year 1882–83 made at Kingua-Fjord, South Georgia and Fort Rae.

The discussion of the earth-currents is based upon the tabulated hourly ordinates from the curves. Instead of measuring a single ordinate for each hour, a planimeter was employed, covering a region on each side of the ordinate sought. A further reduction, by means of trigonometric series, was carried out, in order to get a still closer approximation to the true hourly values.

The diurnal variation of the earth-currents was well marked, showing two principal maxima, and two secondary. An examination of the equations for the mean diurnal variation for the different years shows a slight systematic change from year to year. The mean variation for each year is prettily shown in the excellent vector diagrams, which are a feature of the work. All of the

[1] Die Erdströme im deutschen Reichstelegraphengebiet und ihr Zusammenhang mit den erdmagnetischen Erscheinungen, bearbeitet und herausgegeben von Dr. B. Weinstein. Braunschweig, Friedrich Viewig & Shon, 1900. Text 8° 80 pp. and 4° Atlas of 19 plates.

Digitized by Google

curves show a motion in the direction of the hands of a watch, and in the details of configuration the agreement is also good. A number of interesting deductions are drawn, indicating the dependence of the phenomena upon the Sun's position.

This dependence is no less clearly shown by the annual change in the diurnal variation. A principal maximum of current intensity occurs at the time of the vernal equinox, a secondary one at the summer solstice. The principal minimum is at the winter solstice. The east-west and south-north components for the diurnal variation are very similar throughout the year. As the Sun moves north, the principal waves in the diurnal variation become more pronounced, the secondary waves less so. In winter the reverse is the case, making the winter curves the more complicated. Similar fluctuations are shown in the coefficients of the trigonometrical representation, as well as by a series of vector diagrams for the months and the seasons. The latter are particularly interesting, showing that the mean current in winter is only about half as strong as in summer. Changes of a few days' duration in the character of the curves also occur frequently, which the author attributes to the varying relative position of non-homogeneous portions of the Sun, with reference to the earth.

A patient study was made of the diurnal variation, bringing to light the existence of 36 secondary waves in the course of a day. These occurred about 11 minutes later in the north and south than in the east and west line. The exact number of wavelets may be open to doubt, for the personal equation carries great weight in such investigations; but at least the existence of a system of regularly occurring secondary waves seems established.

The second part of the work is devoted to a discussion of the magnetic records from the stations already mentioned, and the connection between them and the earth-currents. The method of treatment is essentially the same as with the earth-currents, the three rectilinear components of the total intensity being considered. A study of the diurnal variation by means of vector diagrams reveals a more or less definite connection with the Sun's motion. In discussing the direction of the variation, two systems of co-ordinates are used: First, the "geopolar," given by the hour-angle and latitude of the point where the direction at any hour cuts the Earth's surface; and second, the "heliopolar," in terms of the angle with the Sun's direction (heliopolar distance), and the angle which the plane through the direction at any hour and the Sun makes with the equator. The track of the diurnal variation upon the Earth's surface is described in detail, and shows interesting similarities between the different stations. The vector diagram of the total variation is also resolved into components in the directions of the planes of the equator, the meridian, and a plane perpendicular to both; in each case the dependence upon the Sun's position is well marked. The vector diagram in heliopolar coordinates takes the form of a conical surface around the Sun. The variation vector sometimes makes an angle as great as 90° with the direction of the Sun, but never points directly toward it, from which the conclusion is drawn, that if the Sun is the cause of the variation, the influence can not be exerted along a straight line from the Sun to the Earth. We must pass over the many interesting details in the results from the different stations, merely noting that the vectors for the diurnal variation at Fort Rae move in a direction opposite to that at all other stations.

The study of the course of the magnetic variation throughont the year makes it appear that all phenomena occurring in any one season in the southern hemisphere do not, as was formerly supposed, correspond to those of the opposite season in the northern; on the contrary, certain features in the yearly variation seem to indicate the presence of influences outside the Earth, affecting the Earth as a whole. The dependence of the variation upon the latitude of the station is brought out with great clearness.

The above results have an important bearing upon Schuster's theory of the diurnal variation. This theory, as von Bezold has pointed out, requires an *invariable* system of forces, in whose field the Earth rotates. Weinstein's deductions show that excessive deformations of the system would be needed to account for some of his observed phenomena, so excessive, in act, as to lend strong evidence in favor of local influences. We must therefore assume

Digitized by Google

at least two systems of forces, one external, possibly subject to variations, the other of local character.

This part of the work concludes with a discussion of secondary magnetic waves, of which, for Wilhelmshafen in 1884, a mean of 36 were detected in the course of a day, both in the case of declination and of horizontal intensity. The connection between waves in the two elements could not however be established with certainty. It is at least significant that the number of secondary waves here is the same as in the case of the earth-currents.

The work reaches its culmination in Part III, where the relation between terrestrial magnetism and earth-currents is discussed. We regret that space does not permit a more extended review of this interesting chapter. To test first the hypothesis that the earth-currents are simply inductive currents caused by changes in the Earth's magnetism, the author compares the mean diurnal variation in vertical intensity for Vienna in 1884, with that of the earth-currents for the same year. Instead of maxima in increase of vertical intensity corresponding to maximal current, etc., we find almost the reverse to be the case. The author therefore confines himself to the question, whether variations in magnetism are partly due to the earth-currents. If the *vertical* component of the current changes were known, the problem would be much simplified; in lieu of this, ingenious methods have to be resorted to in order to gain such circumstantial evidence as possible. Even in a horizontal directiou only the mean components for certain distances in two directions are known, while the true path of the current lies wholly in the dark. An increase in one or both of these components would not of necessity cause an increase in any one of the magnetic elements, since any such effect might be more than counterbalanced by changes in the direction of the earth-current.

A comparison of the mean absolute values of vertical magnetic intensity and earth-current intensity for the 24 hours tends to strengthen the theory. To explain certain peculiarities in the former, assumptions are made concerning the variation in direction of flow of the earth-currents, which in turn would require an increase in the magnetic horizontal intensity; and this increase is is in fact found to take place. When the changes in azimuth of the horizontal components of earth-current and magnetic intensity are compared, the evidence is weaker, though still in the same direction. The comparison of changes from season to season is also favorable, certain minor variations agreeing remarkably well.

As concluding evidence, reference is made to the parallelism in the occurrence of sudden disturbances. By picking these out on the declination traces in Vienna and comparing them with corresponding disturbances on the Berlin earth-current records, the difference in longitude between the two cities could be quite accurately determined. A rigid comparison would of course be possible only if both direction and amount of the resultant disturbances were known, which is far from being the case in the present state of the science.

The author states his conviction that almost the whole of the variations observed by magnetometers are due to earth-currents which act upon the instruments as upon galvanometers. An immense amount of patience and skill has been devoted to compilation of results, and it must be admitted that the evidence is favorable to this theory. As a working hypothesis it may be found of great value; but our knowledge of the phenomena, and particularly the mass of actual observations, must be vastly extended before we can finally accept the solution as a physical fact.

U. S. C. AND G. S. W. G. CADY.

JAR'S EARTH-CURRENT EXPERIMENTS.[1]

Herr E. Jar describes in the "Elektrotechnische Zeische Zeitschrift (Berlin) March 6," the results of a long series of researches upon telluric currents by means of electrodes buried in the ground and the conclusion reached from them. With metallic plates in the same metal he has concluded that two plates of equal dimensions, placed in the magnetic meridian so that the north plate is the deeper of the two, will show a difference in potential that

Digitized by Google

is constant for such a condition. If the southward plate is the deeper the direction of the current is inverted. To give an idea of the magnitude of the phenomena observed, the author states that for distances of about 300 meters, plates of one by two meters in size buried a depth of from one to five meters showed a variation in tension of from one to fifty millivolts. The intensity of the current in the conductor connecting the two is exceedingly variable, and observations on it can only be made at exceptional moments.

MAGNETIC OBSERVATIONS AT ZI-KA-WEI, CHINA, IN 1899.[1]

This paper gives the results of the absolute and variation determinations made during the year 1899. The absolute observations were made at irregular intervals, and the values obtained for the three elements are tabulated. The self-recording instruments consist of a declinometer, a bifilar, and a balance. For a description of the instruments the author refers the reader to the Bulletins for 1897.

The values of the daily and monthly means are discussed month by month so as to give in a general way the progress of the declination, inclination, total intensity, and horizontal and vertical components. The diurnal variations of the same elements are treated in a similar manner.

All disturbances are measured and recorded in the following way: the word ondulation, abbreviated *ond.*, is used to designate a temporary departure from the normal curve. By *ondulation double* is meant a departure, first to one side then to the other of the normal curve. Movements of slight amplitude and short duration are termed *crochets*. The following specimens will illustrate the method of recording:

January 3.—4^h *ond.* (+12+1′); 9^h *ond.* (—5); 18^h to 21^h *ond. double* (+10—10).
March 6.—15^h to 17^h *H crochets nombreux*; 21^h 25^m pulsations; 21^h to 23^h *ond. double* (+0.′5—0.′5).

The first of these is to be read thus: at 4^h, *ondulation* of amplitude +0.00012 *c. g. s.* on the bifilar and +1′ on the declinometer. At 9^h, *ondulation* of amplitude —0.00005 on the bifilar. From 18^h to 21^h double *ondulation* on the bifilar, first amplitude +0.00010, second —0.00010.

Accompanying the paper are reproductions of the traces for markedly disturbed days. There are also three tables, the first giving for the month of April the daily means for declination, inclination, total intensity, and X and Y components, together with the maximum and minimum and daily range of declination. The second table gives for the same month the hourly means for declination, inclination, total intensity, and the X, Y, Z components. In the third table are given the monthly means for the three elements and total and vertical intensities, together with the mean values of the maximum and minimum and daily range of declination.

Systematic observations of the Sun were made for detecting and recording the appearance of Sun spots, and reports of earthquakes were received and recorded. While in most cases no apparent magnetic disturbance accompanied the presence of Sun spots or earthquakes, yet, now and then a simultaneous occurrence was noted. In particular, a prolonged magnetic disturbance lasting from June 27th to 30th was accompanied by a large group of Sun spots said to be visible to the naked eye. On November 29th, a magnetic disturbance accompanied an earthquake that was plainly felt at Kyûshû. Moreover, the curve representing an earth current which appeared September 15th in the cable from Nagasaki to Shanghai bears a striking resemblance to the horizontal intensity trace for the same period. Two large prominences on the earth-current curve appear simultaneously on the intensity trace, the declination trace, however, being almost unaffected.

U. S. C. and G. S. Magnetic Observatory, Baldwin, Kansas.

WM. F. WALLIS.

[1] Bulletin Mensuel de l'Observatoire Magnétique et Météorologique de Zi-ka-wei, China; tome XXV, Année 1899. Changhai, 1901, Extrait, pp. 8+10+(55-64)+(105-114)+(159-166 + (211-220); 24 x 33 cm.

Digitized by Google

RECENT PUBLICATIONS

BATAVIA OBSERVATORY. Observations made at the Magnetical and Meteorological Observatory at Batavia. Volume XX, 1897, Batavia, 1898, 26 x 36 cm. 8+214 pp. [Issued under the directorship of Dr. van der Stok. In the preface it is stated that the method of reduction of magnetic observations in use at the Observatory is explained in the supplement to Volume VI, and in the preface to Volume VII, also in "Communications from the International Polar Commission," page 305, and "Archives Néerlandaises," t. XIX. The tables give the observations and results for 1897.]

Volume XXI, 1898, Batavia, 1899, 26 x 36 cm. 12+216 pp. [Preface states that the Observatory will now be known as the "Royal Magnetical and Meteorological Observatory." The volume is issued under the directorship of S. Figee, the temporary director, now permanent director of the Observatory. The usual tables of magnetic observations for 1898 and of results are given. Unfortunately the long and valuable series of magnetic observations at the Observatory was interrupted owing to the injurious influence of electric car lines running at less than 250 meters from the Observatory. In addition to the usual meteorological tables and results the seismometric records at Batavia 1898-99, and the list of earthquakes in the E. I. Archipelago, 1899, are given.]

Volume XXII, 1899, Part I, Batavia, 1900, 26 x 36 cm. 12+204 pp. [Contains the 1899 magnetic observations and results, January to March, after which the electric car effects began to appear. Besides the meteorological observations, the seismometric records for 1899 are given. Appendix I, *Dr. W. van Bemmelen*, die Säkular-Verlegung der magnetischen Axe. (cf. T. M. Volume VI, p. 73.) Appendix II, Catalogue of the Library.]

Volume XXII, Part II, Batavia, 1901, 26 x 36 cm. XIV+2+100 pp. Frontispiece and 3 plates. [Contains the results of the magnetic observations made during the period 1886–99.]

BARACCHI, PIETRO. Results of Observations in Meteorology and Terrestrial Magnetism made at the Melbourne Observatory and other localities in the State of Victoria, Australia, from January 1–June 30, 1901. Melbourne, 1901. 48 pp; 15½ x 24½ cm. [Contains no magnetic results.]

BENJAMIN, PARK. A History of Electricity from antiquity to the days of Benjamin Franklin. Published by John Wiley & Sons, New York. Bound in cloth, price $3. Pp. 612, 15 x 22 cm. [The same as the author's well known book, entitled "The Intellectual Rise in Electricity." London, 1895.]

COAST AND GEODETIC SURVEY, UNITED STATES. Lines of Equal Magnetic Declination and of Equal Annual Change in the United States for 1902. Published at Washington, D. C., February, 1902. 57 x 70 cm.

HADDEN, D. E. Auroral Phenomena at Alta, Iowa [evening of March 29, 1902].

HELLMANN, G. Neudruck von Schriften und Karten über Meteorologie und Erdmagnetimus: No. 14. Meteorologische Optik 1000–1836, Berlin, A. Ascher & Co., 1902, price 11 marks. [This is doubtless the last number of this interesting and valuable series of reprints of early works on terrestrial magnetism and meteorology.]

RAJNA, M. Sull' excursione diurna della declinazione magnetica a Milano in relazione col periodo delle macchie solari. Repr. Rend. R. Ist. Lombardo XXXV, 1902. Pp. 10. 8°.

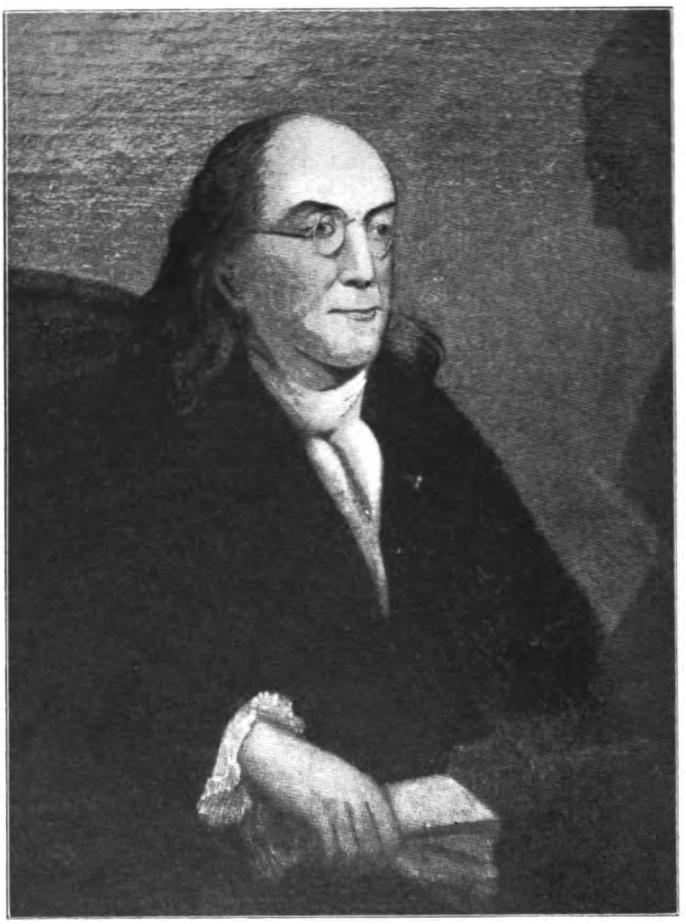
STONYHURST COLLEGE OBSERVATORY. Results of Meteorological and Magnetical Observations by Rev. W. Sidgreaves, S. J., 1901. Clitheroe, 1902. 12½ x 18½ cm. 6+79 pp.

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS

Digitized by Google



BENJAMIN FRANKLIN.

[From the Gainsborough portrait in the University of Pennsylvania.]

Digitized by Google

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VII DECEMBER, 1902 NUMBER 4

RESULTS OF INTERNATIONAL MAGNETIC OBSERVATIONS MADE DURING THE TOTAL SOLAR ECLIPSE OF MAY 18, 1901, INCLUDING RESULTS OBTAINED DURING PREVIOUS TOTAL SOLAR ECLIPSES.

By L. A. Bauer.

Purpose of the Observations.

During the total solar eclipse of May 28, 1900, a slight magnetic effect that appeared to be directly associated with the passage of the shadow cone from place to place was observed at various stations, distributed within or close to the belt of totality, in the southeastern part of the United States.[1]

The analysis of the effect showed that it was not a phenomenon similar to a cosmical magnetic disturbance, the beginning of which takes place practically simultaneously over a very large area and, in many instances, over the entire earth, but that the occurrence of the various phases of the effect was closely related to the times of totality at the various stations. Furthermore, the indications were that the source of the effect was to be attributed to some change which occurred outside of the Earth's crust. It was also shown that this effect differed from an ordinary cosmical magnetic storm in that it began, progressed, and ended gradually; in brief, that it consisted of a wave of the periodic variation kind so that it was

[1] See Terrestrial Magnetism, Vol. VI, pp. 143–165.

Digitized by Google

not proper to term it a "disturbance" or "perturbation," but a magnetic oscillation or variation.

Since similar effects are not obtained by mere abstraction of the Sun's rays in atmospheric regions accessible to us, the assumption was that the observed magnetic effect was due to some change produced in the *upper* atmospheric strata—probably in their electric condition—by the withdrawal of the Sun's rays due to the interposition of the Moon between the Sun and the Earth. If this were true we had manifestly disclosed to us a phenomenon, the elucidation of which is of the utmost importance to the unfolding of the cause or causes producing the diurnal variation of the Earth's magnetism. For, if a magnetic effect is produced by the screening of the Earth by the Moon during a solar eclipse, it is evident that we should get a similar effect by the daily eclipse of one side of the Earth by the Earth itself. And if we investigate the progress of the diurnal variation during the night hours, it would appear that the same phenomena of retardation and interruption in the usual course of the curve are discernible, as in the case of the diurnal variation curve during the time of totality of a solar eclipse.

To further test these results, an appeal was made for international co-operation in magnetic and allied observations during the total solar eclipse of May 17–18, 1901.[1]

The track of the shadow cone for this eclipse (see Fig. 1)[2] extended from Madagascar and Mauritius across the Indian Ocean and over the islands of Malaysia, the duration of totality for the stations in Sumatra being over six minutes. The exceptionally long duration presented, therefore, a favorable opportunity for further verification. The repetition of the observations was furthermore interesting since the belt of totality of the present eclipse lay in the *southern* magnetic hemisphere, whereas the one of the year before was in the *northern*. Additional light as to the character of the variation, if it were again observed, was, therefore, promised. The physical conditions, however, for obtaining a number of stations distributed along the belt of totality, as was done in 1900, and thus testing whether the magnetic effect again followed directly in the wake of the shadow cone, were not as favorable as in the year before, owing to the geographical situation of the present belt.

[1] TERRESTRIAL MAGNETISM, Vol. VI, p. 166.

[2] This figure, as also No. 3, has been reproduced from the Report of the party of the Massachusetts Institute of Technology, elsewhere cited.

Digitized by Google

Nevertheless, valuable data have been obtained for the verification of this matter. Results are given later for three stations within the totality belt, viz: from Mauritius Magnetic Observatory near the western extremity of the belt and from two stations in Sumatra; also for two stations outside of the belt, viz: the Batavia Magnetic Observatory and the Manila Observatory.

Besides the stations mentioned, observations were made at 28 stations distributed over the entire globe. The prime purpose of making the observations over the whole Earth was to furnish the means for separating a possible eclipse magnetic effect from a con-

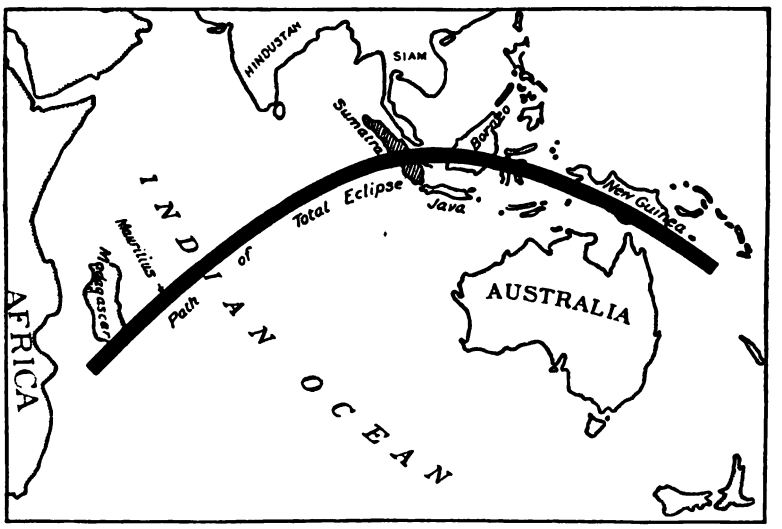


FIGURE 1. Belt of Totality for Solar Eclipse, May 18, 1901.

temporaneous magnetic storm of the usual type. The eclipse effect, for instance, doubtless would be confined to a very small belt, whereas a customary magnetic storm, in conformity with the usual experience, would manifest itself at practically the same moment of time over a very large area and thus reveal itself at stations far from the totality belt.

In response to the appeal simultaneous magnetic observations were made on May 17th from 14 to 21 o'clock, Greenwich mean astronomical time, an interval amply covering the time of the eclipse. The scheme of work proposed was as follows:

1. Simultaneous magnetic observations of any or all of the elements,

Digitized by Google

according to instruments at the observer's disposal, every minute from May 17, 14 h to 21 h, Greenwich mean, astronomical time.[1]

[To insure the highest degree of accuracy attainable, the observer was to begin work early enough to have everything in complete readiness in proper time, and reference was made to the directions successfully carried out by all the Coast and Geodetic Survey magnetic parties in 1900 and given in T. M., Vol. VI, p. 146–7.]

2. At magnetic observatories all necessary precautions were to be taken, so that the self-recording instruments would be in good operation, not only during the proposed interval, but also for some time before and after, and eye-readings were to be taken in addition, wherever circumstances permitted.

3. Such meteorological observations were requested as were possible for the observer at convenient periods (as short as possible) throughout the interval. It was suggested that temperatures, *e. g.*, be read every fifth minute (directly after the magnetic reading for that minute).

4. Observations of atmospheric electricity and of earth currents whereever possible, and of any other concomitant phenomena of importance were to be fully noted.

5. Observers in the belt of totality were requested to take the magnetic readings every fifteen seconds during the time of totality, and to read temperatures as frequently as possible.

The request was made that observers send as soon as possible a full report of their work for publication in this Journal, care being taken to include all essential details.

For America the interval of observation occurred during the night hours of May 17th and 18th, civil dates, while for Europe, Asia, Africa, and Australia, it occurred during the morning or afternoon hours (according to longitude of station) on May 18th, civil date.

Most of the reports of those who took part in this international work have been published in the previous issues of the Journal and the remainder of the results will be found incorporated in the following tables.

ADDITIONAL DATA.

The following additional data have been received since the publication of the separate reports:

Stonyhurst, England.—From the director, Father Sidgreaves, copies of

[1] CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time				Longitude from Gr.		Latitude	
Eclipse begins	May 17 d	14 h	59 m	.9	51° 34′.4 E.		20° 21′.9 S.	
Central eclipse begins	17	15	57	.6	40 11 .2 E.		27 27 .6 S.	
Central eclipse at noon	17	17	28	.8	96 51 .9 E.		2 07 .1 S.	
Central eclipse ends	17	19	10	.2	156 53 .6 E.		12 49 .0 S.	
Eclipse ends	17	20	07	.9	145 04 .5 E.		5 38 .0 S.	

Digitized by Google

the photographic traces and the hourly values of declination and horizontal intensity for May 17th and 18th. [1 mm. of ordinate for $D=1'.128$ and for $H=5,17\gamma$.]

Munich, Germany.—The scalings of the D and H magnetograph were supplied by the present observer in charge, Dr. J. B. Messerschmidt, for every minute from 14^h to 21^h; on account of the disturbances from the electric car lines, vertical intensity observations have been discontinued.

Pawlowsk, Russia.—Mr. Dubinsky, in charge of the Observatory, furnished the results of the eye-readings (D, H, and Z) for almost every minute from 14^h to 20^h 59^m.

Bombay, India.—Prof. Moos forwarded the D, H, and Z scalings for every five minutes from 14^h to 21^h. The reductions to absolute values were made by one of my assistants. [1mm. $D=1'.131$, 1mm. $H=5.08\gamma$, and 1mm. $Z=16.1\gamma$.]

Manila, Philippines.—Father Saderra Maso, Assistant Director of the Philippine Weather Bureau, furnished the scalings of the magnetograph (D, H, and Z) for every two minutes for the prescribed interval, the hourly values for the entire month and the meteorological data for May, and copies of traces for May 18th; all necessary corrections and reductions were made by him.

Karang Sago and Batavia.—The data utilized in this paper were obtained partly from van Bemmelen's published Report[1] and partly from information which Dr. van Bemmelen directly furnished. The observations at Karang Sago consisted entirely of variation observations (D and H) begun May 9th and continued until the day of the eclipse inclusive. Two recording cylinders—one with revolving time of six hours, the other of twenty-four hours—were employed, during the period May 9th–17th; the twenty-four-hour cylinder registered during the day hours and the six-hour cylinder during the night. On May 18th, the six-hour cylinder was unfortunately introduced just after first contact, and owing to the breaking of the suspension fiber of the eye-reading declinometer, it was not possible to connect the declination records on the twenty-four-hour cylinder with those on the six-hour one, resulting thus in the loss of an interesting part of the curve immediately before first contact.

The author did not publish the original declination scalings, but the $H \Delta D$ values instead; the ΔD quantities were deduced by one of my assistants and combined into five-minute means (See Table II). It is not entirely clear from van Bemmelen's report whether the ΔH quantities were corrected for changes in temperature or not—presumably they were. If not, then a correction for temperature change amounting to about 4γ would have to be proportionately distributed over the interval covered by the observations.

[1] Total Solar Eclipse, May 18, 1901. Magnetic Observations at Batavia and Karang Sago (Sumatra) by *W. van Bemmelen. Repro. from Natuurkundig Tijdschrift voor Ned-Indie, deel LXI, afl.* 3, *Amsterdam*, 1901, *pp.* 173–194. 16×24 *cm.*

Digitized by Google

1mm. of D ordinate = 1′.10 and 1mm. of H ordinate = 1.0γ.

Under the date of April 21, 1902, Dr. van Bemmelen writes that the values of the variations for May 17th published in his Report are not quite correct, saying that: "Die Werte (relativen) für D stimmen nicht ganz mit jenen der Publication, was daher rührt, dass das Magnetogram nicht ganz unzweideutig ist. Ich meine aber die jetzige Auffassung sei die wahre."

Corrected values of the magnetic variation observations at Karang Sago for May 17, 1901.

Local M. T.	Δ D	Δ H	Local M. T.	Δ D	Δ H	Local M. T.	Δ D	Δ H	Local M. T.	Δ D	Δ H
h m	′	γ	h m	′	γ	h m	′	γ	h m	′	γ
8 00a	1.2	20.3	11 00a	0.5	65.7	2 00p	1.4	44.2	5 00p	0.3	9.5
15	1.1	26.4	15	0.7	67.0	15	1.3	49.0*	15	0.4	7.7
30	0.7	35.2	30	0.8	67.9	30	1.3	34.5	30	0.5	6.2
45	0.5	36.1	45	0.5	68.9	45	1.1	30.8	45	0.5	3.7
9 0	0.2	43.1	12 0p	0.4	69.5	3 0	0.9	28.1	6 00p	0.6	1.3
15	0.4	46.5	15	0.4	69.2	15	0.7	23.8			
30	0.3	40.6*	30	0.3	68.0	30	0.4	21.1			
45	0.4	54.0	45	0.3	65.7	45	0.3	18.7			
10 0	0.3	58.0	1 0	0.7	63.1	4 0	0.2	17.7			
15	0.4	61.5	15	1.1	56.3	15	0.1	15.3			
30	0.5	63.2	30	1.3	49.4	30	0.0	13.2			
45	0.7	63.6	45	1.3	45.8	45	0.1	11.7			
11 00a	0.5	65.7	2 00p	1.4	44.2	5 00p	0.3	9.5			

[To obtain Greenwich mean time, subtract from the observed times, $6^h\ 42^m.3$.].

The following additional results of the variation observations for May 18th have been supplied.

May 18, 1901.

Gr. M. T.	Δ D	Δ H	Gr. M. T.	Δ D	Δ H
h m	′	γ	h m	′	γ
1 00a	−1.3	−18.7	45	−2.3	+36.3
15	−1.5	−11.4	3 0	−1.7	+38.9
30	−1.7	−3.8	15	−1.3	+41.0
45	−1.7	+6.2	30	−1.0	+42.2
2 0	−1.8	+15.1	45	−0.6	+41.8
15	−1.9	+24.0	4 0	−0.3	+42.0
30	−2.2	+33.5	15	−0.0	+39.1

* Two values of Δ H in above table appear to me to be erroneous, viz: at $9^h\ 30^m$ the reading should probably be 50.6 instead of 40.6; similarly at $2^h\ 15^m$ the reading is probably 39.0 instead of 49.0.—Ed.

Digitized by Google

Referring to these observations, Dr. van Bernmelen says: "Hence East declination was less from 1^h–4^h than at $4^h\,15^m$; however, these Δ D's may not join on with the subsequent values on account of change of cylinder." There is no similar trouble with the Δ H's.

The following extract is made from van Bemmelen's report;

"The electric car company at Batavia stopped its traffic from $11^h\ 30^m$ a. m.—$2^h\ 30^m$ p. m., during which time two well-trained Javanese assistants read the variation apparatus (Wild pattern). In regular succession each of the three instruments was read every thirty seconds. Owing to a misunderstanding, however, the thermometers were not read.

"The Adie magnetograph registered undisturbedly; the new and very sensitive thermographs with which both bifilar and balance were recently supplied, gave full information about the variation of the temperature, for which reason the eye-readings of Wild's instruments have been reduced to the readings of the magnetograms. The registration of the magnetograph before and after the day of the eclipse, although more or less disturbed by the electric car, admits of rough reading.

"The normal variation for the horizontal intensity and declination has been made up from the readings of the magnetograms in the same manner as at Karang Sago.

"From the readings of the Wild instruments the values of *H* and *D* on the full minute Greenwich time have been graphically interpolated.

"Wild's balance not having sufficient sensitiveness, only the registration of the magnetograph-balance has been made available.

"The scale values were:

Wild's Variation Apparatus.	Adie Magnetograph.
H, 1 scale division = 2.77γ	*H*, 1 mm. = 5.3γ
D, 1 " " = 0.′370	*D*, 1 " = 1′.14
	V, 1 " = 1.95γ

"The magnetograms of May, 1901, can not be used for the normal movement of the vertical intensity, owing to the great disturbances produced by the electric cars. Instead of May of this sun-spot minimum 1900-1901, May of the preceding minimum, viz.: May, 1887, was chosen.

Mean relative hourly values of the magnetic components at Batavia.

Local mean time	h 8	h 9	h 10	h 11	h noon	h 1	h 2	h 3	h 4	h 5	h 6
Greenwich M. T.	0.9	1.9	2.9	3.9	4.9	5.9	6.9	7.9	8.9	9.9	10.9
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
May 9–17, 1901 Δ*H*	28.6	31.8	39.8	43.5	38.2	20.2	21.7	12.7	4.3	0.5	0.0
May 9-17, " *H*Δ*D*	13.5	23.1	27.7	27.6	22.1	15.8	8.9	4.4	0.0	3.2	7.8
May, 1887 Δ*Z*	7.3	4.8	1.5	0.0	1.5	1.5	3.6	6.7	12.5	19.5	22.8

Digitized by Google

The table of ΔH, $H\Delta D$ and ΔZ for May 18, 1901, at Batavia having already been printed in detail by van Bemmelen, only the five-minute means as based thereon are given in the following tables.

Melbourne, Australia.—Director P. Baracchi forwarded *D*, *H*, and *Z* values for every five minutes from 14^h to 21^h May 17th, as also the hourly values for May 17^d 0^h 0^m to May 19^d 0^h 0^m, Greenwich mean astronomical time and meteorological conditions May 17th. The magnetic data "were deduced from the measures of ordinates on the photographic curves; the values of the respective base lines were obtained by interpolation from the values at the two nearest dates, following and preceding, on which absolute observations had been made; namely, April and May 28th. The ordinates for the horizontal and vertical components were not corrected for temperature, as the range of variation of temperature during the period in question was under 1° F."

El Contadero, Mexico.—Director Felipe Valle of the Observatorio Astronomico Nacional Mexicano, furnished a series of *D* and *H* variation observations made under his direction with the Mascart instruments by M. Moreno y Anda.

Owing to the disturbing influence of the electric cars in the city of Mexico and vicinity, the place finally selected was El Contadero, situated W. S. W. 16 kilometers from Tacubaya, its geographical co-ordinates being approximately the following: latitude, N. 19° 20′.8, longitude, W. of Greenwich, 99° 18′.3; altitude, 2,880 meters. The observations were made in a house constructed of non-magnetic materials, every minute from 8^h 10^m p. m. of May 17th until 2^h 10^m a. m. May 18th, or from 14^h 48^m to 20^h 48^m, May 17th, Gr. m. astr. time. Only the results of the *D* observations are given in the following tables as the *H* values appear to be affected by a drift in the base line.

CORRIGENDA AND ALTERATIONS.

de Bilt, Vol. VI, pp. 131-134.

All of the *D*, *X*, and *Y* values since publication have been replaced by Dr. Snellen by revised ones. Furthermore, in the *H* column for 13^h 21^m read 65.1 instead of 68.1, for 14^h 09^m, 63.9 instead of 64.9, for 15^h 04^m, 67.2 instead of 66.3, for 17^h 01^m and 17^h 02^m, 64.7 instead of 64.9, and for 17^h 05^m and 17^h 06^m, 63.9 instead of 63.7. Also in the *Z* column, for 16^h 54^m read 99.0 instead of 97.0.

The five-minute means in this paper are based on the revised results.

Digitized by Google

Groningen, Vol. VI, p. 128, and VI, p. 172.

The author's name should be *H.* Haga not *W.* Haga. Instead of D_o (West) plus tabular numbers, it should read *minus* tabular numbers; *i. e.*, *increasing tabular numbers means decreasing west declination.*

In Table II of present paper, the series has been reversed by subtracting the originally published quantities from $+5'$, so that now *increasing* tabular numbers means *increasing* west declination.

Wilhelmshaven.

P. 167, Vol. VI, 12th line, read 13° 02′.16 instead of 13° 21′.6. P. 168, Table II, the quantities given are not *five-minute means* but the *single* values every *fifth* minute. These are the quantities likewise given in Table II of present paper.

Pola.

P. 124, Vol. VI, for *H* at $18^h\ 34^m$ read 210 instead of 200.

Mauritius.

P. 184, Vol. VI, first line of footnote 2, read: "The traces were *scaled*" instead of *sealed.* The ΔH (variations of *H*) values should all have the negative sign, since increasing ordinates on the horizontal intensity trace correspond to decreasing values of *H.* In Table III of present paper the *H* series has been reversed by subtracting the originally published ΔH values each from 40.0 γ, so that *increasing* numbers now signify *increasing* intensity.

Sawah Loento.

P. 181, Vol. VI, 3d line from bottom, instead of *increasing* scale readings corresponding to *decreasing* east declinations, it was found later that they correspond to *increasing* east declination. The declinations originally published for May 17th and 18th are accordingly erroneous. *The values to be found in Table II of present paper are based on the corrected ones.*

Rocky Mount.

Plate VII opposite p. 154, Vol. V, the space marked 2° C. for temperature should have been marked 5° C.

Digitized by Google

Christchurch observations.

Owing to a misinterpretation by the editor of the manuscript furnished by the observer, an error was introduced in the report of the magnetic observations made at Christchurch, New Zealand, May 17–18, 1901, as published on pp. 179 and 180, Vol. VI of this Journal. The observations were taken on the full minute New Zealand standard time, and not according to local mean time. Consequently the first observation was at $14^h\ 09^m$ G. M. T., and the last at 21^h G. M. T., the New Zealand standard meridian being $11^h\ 30^m$ east of Greenwich. The times in the table on page 180 are therefore all one minute too small.

FACTS PERTINENT TO STATIONS.

TABLE I.

No	Station.	Country.	Latitude.	Longitude E. of Gr.	Correction to reduce Local Mean Time to Gr. M. T.	Approximate Magnetic Elements.				Variations observed.	Report published in T. M.
						D	*I*	*H*	*Z*		
			° ′	° ′	h m	° ′	° ′	10γ	10γ		
1	Stonyhurst	England	53 51N	357 32	+0 09.9	18 08 W	68 46N	1737	.....	DH	VII, No. 4
2	Val Joyeux	France	48 49N	2 01	−0 08.1	15 12 W	64 59N	1968	4218	DHZ	VI, 125
3	Flushing	Holland	51 27N	3 35	−0 14.3	14 46 W	.....	1866	.....	DH	VI, 135
4	de Bilt (Utrecht)	Holland	52 05N	5 11	−0 20.7	13 47 W	.....	1856	4350	DHZ	VI, 129[1]
5	Groningen	Holland	53 13N	6 34	−0 26.3	.....	.....	1845	.....	DH	VI, 128, 172[1]
6	Wilhemshaven	Germany	53 32N	8 09	−0 32.6	12 26 W	67 46N	1813	.....	DH	VI, 167[1]
7	Munich	Germany	48 09N	11 37	−0 46.4	10 22 W	.....	2064	.....	DH	VII, No. 4
8	Potsdam	Germany	52 23N	13 04	−0 52.3	9 51 W	.....	1887	4340	DHZ	VI, 169
9	Pola	Austria	44 52N	15 51	−1 03.4	9 20 W	60 13N	2223	3885	DH	VI, 123[1]
10	Bucharest	Roumania	44 25N	26 06	−1 44.4	4 11 W	.....	.....	.....	D	VI, 171
11	Pawlowsk	Russia	59 41N	30 29	−2 01.9	0 33 E	.....	1640	4704	DHZ	VII, No. 4
12	Mauritius	E. Coast Afr.	20 06 S	57 33	−3 50.2	9 27 W	54 11 S	2382	.....	DHZ	VI, 184[1]
13	Colaba (Bombay)	India	18 54N	72 49	−4 51.3	0 20 E	21 21N	3743	1463	DHZ	VII, No. 4
14	Dehra Dún	India	30 19N	78 06	−5 12.4	2 46 E	.....	3355	.....	DH	VI, 173
15	Karang Sago	Sumatra	1 19 S	100 34	−6 42.3	..... E	.....	.....	.....	DH	VII, No. 4
16	Sawah Loento	Sumatra	0 41 S	100 47	−6 43.1	0 51 E	.....	.....	.....	D	VI, 181[1]
17	Batavia	Java	6 11 S	106 49	−7 07.3	1 05 E	29 47 S	3670	.....	DHZ	VII, No. 4
18	Manila	Philippines	14 35N	120 58	−8 03.9	0 51 E	16 10N	3815	1106	DHZ	VII, No. 4
19	Zi-ka-wei	China	31 12N	121 26	−8 05.7	2 21 W	45 48N	3275	3342	DHZ	VI, 177
20	Melbourne	Australia	37 50 S	144 58	−9 39.9	8 24 E	.....	2334	5622	DHZ	VII, No. 4
21	Christchurch	New Zealand	43 31 S	172 38	−11 30.5	..... E	.....	.....	.....	D	VI, 179
22	Sitka	Alaska	57 03N	224 40	+9 05.0	29 50 E	74 48N	1541	.....	D	
23	El Contadero	Mexico	19 21N	260 42	+6 37.6	7 32 E	.....	3393	.....	DH	
24	Austin	Texas	30 15	262 15	+6 31	3 07 E	.....	.....	.....	DH	
25	Baldwin	Kansas	38 47N	264 50	+6 20.7	8 23 E	68 33N	2195	.....	DH	
26	Little Rock	Arkansas	34 47N	267 42	+6 09.2	6 36 E	.....	.....	.....	D	VII, No. 4
27	Toronto	Canada	43 40N	280 30	+5 18.0	5 28 W	.....	1651	.....	DH	
28	Gaithersburg	Maryland	39 08N	282 48	+5 08.8	6 31 W	70 48N	1980	.....	D	
29	Cheltenham	Maryland	38 44N	283 10	+5 07.3	5 03 W	70 23N	2019	.....	DHZ	
30	Vieques I	Porto Rico	18 08N	294 33	+4 21.8	1 10 W	49 10N	2953	.....	D	

[1]See corrections in present paper among "Corrigenda."

Digitized by Google

TABLES OF RESULTS.

In the following tables are given for each station, except for a few cases, the five-minute means of the results of the observations. These five-minute means are usually the means of 3–6 readings arranged symmetrically with reference to the full fifth minute. If the readings were made every minute, the mean for $14^h\ 05^m$, for example, would be the mean of the readings at 14:03, 14:04, 14:05, 14:06, and 14:07. In this way errors of observation or in scaling the magnetograms, or such errors as are due to change of observer (as shown at almost every station where a change of observers, during the interval, took place) were somewhat smoothed out. *The quantities given in these tables form the basis of the present investigation and should be used by other investigators in place of those given in the separately published reports into which have crept various errors, as shown by the table of "Corrigenda."* The preparation of these results, as can easily be understood, has involved considerable labor. They will be useful in other investigations besides the present one.

It gives me pleasure to make grateful acknowledgment to all those who have taken part in the observations and in the reductions, and I trust that the results obtained will compensate for the time and labor spent upon this investigation.

Digitized by Google

TABLE II. Results of the magnetic declination observations made on May 17, 1901, from 14^h to 21^h, Greenwich mean astronomical time.

Greenwich mean astr. t. May 17, 1901.	1. Stonyhurst, West 18° +	2. Val Joyeux, West 15° +	3. Flushing, West 14° 40′ +	4. de Bilt, West 13° 40′ +	5. Groningen, West D_0 +	6. Wilhelmshaven, West 12° 15′ +	7. Munich, West 10° 15′ +	8. Potsdam, West 9° 45′ +	9. Pola, West 9° 10′ +	10. Bucharest, West 4° 08′ +	11. Pawlowsk, East 0° 30′ +	12. Mauritius, West D_0 +	13. Colaba, East 0° 20′ +	14. Dehra Dún, East 2° 40′ +
h m	′	′	′	′		′	′	′	′	′	′	′	′	′
14 0	8.2	11.4		6.36							3.3	1.90	4.07	
5		11.2	5.82	6.50		8.47	6.96		9.80	3.32	3.30	1.90	4.16	8.87
10		11.2	5.62	6.26		8.32	6.76		9.80	3.24	3.18	1.90	4.30	9.00
15		11.2	5.72	6.26		8.17	6.80		9.78	3.32	3.08	1.89	4.39	8.98
20		11.4	5.64	6.22		8.25	6.76		9.70	3.28	3.08	1.87	4.47	8.89
25		11.5	5.66	6.46	4.74	8.40	7.08		9.70	3.08	3.22	1.85	4.52	8.90
30		11.5	5.78	6.62	4.95	8.47	7.22		9.72	3.04	3.28	1.82	4.58	8.86
35		11.4	5.91	6.62	4.94	8.55	7.04		9.86	3.04	3.06	1.80	4.69	8.89
40		11.2	5.64	6.38	4.65	8.40	6.74	6.46	9.90	3.08	2.84	1.74	4.69	8.86
45		11.1	5.60	6.20	4.52	8.17	6.62	6.20	9.88	3.08	2.82	1.65	4.69	8.78
50		11.2	5.55	6.12	4.38	8.10	6.50	6.20	9.72	2.92	2.80	1.55	4.69	8.77
55		11.2	5.60	6.10	4.41	8.10	6.52	6.20	9.52	2.80	2.76	1.47	4.69	8.78
15 0	7.7	11.2	5.50	6.26	4.51	8.25	6.68	6.20	9.50	2.64	2.80	1.46	4.69	8.49
5		11.1	5.59	6.20	4.51	8.32	6.54	6.19	9.52	2.52	2.66	1.46	4.69	8.35
10		11.0	5.44	6.04	4.26	8.03	6.44	6.09	9.68	2.16	2.48	1.42	4.67	8.32
15		11.0	5.42	5.82	4.18	7.73	6.40	6.02	9.66	1.92	2.38	1.40	4.62	8.26
20		11.0	5.44	5.78	4.08	7.73	6.40	5.91	9.44	1.80	2.30	1.40	4.62	8.17
25		11.0	5.46	5.76	4.02	7.73	6.34	5.82	9.30	1.80	2.30	1.40	4.58	8.09
30		11.0	5.42	5.58	3.82	7.65	6.30	5.40	9.22	1.76	2.02	1.40	4.47	8.03
35		10.8	5.50	5.50	3.74	7.58	6.22	5.30	9.14	1.72	1.76	1.40	4.36	7.94
40		10.8	5.41	5.18	3.54	7.21	6.14	5.21	9.06	1.60	1.80	1.43	4.28	7.77
45		10.7	5.51	5.20	3.45	7.13	6.02	5.20	8.98	1.64	1.88	1.46	4.19	7.64
50		10.7	5.51	5.18	3.42	7.21	5.88	5.20	8.90	1.60	1.84	1.53	4.07	7.51
55		10.7	5.23	4.98	3.29	7.13	5.80	5.15	8.90	1.52	1.86	1.68	4.02	7.35
16 0	6.7	10.7	5.33	5.04	3.38	7.13	5.80	5.19	8.88	1.52	2.10	1.83	3.79	7.28
5		10.8	5.44	5.14	3.40	6.98	5.76	5.09	8.74	1.56	1.84	1.96	3.68	7.08
10		10.5	5.35	4.96	3.20	6.98	5.60	4.92	8.80	1.40	1.74	2.09	3.62	6.94
15		10.3	5.15	4.72	3.02	6.98	5.50	4.87	8.72	1.40	1.72	2.16	3.45	6.70
20		10.0	4.94	4.52	2.91	6.69	5.44	4.65	8.64	1.44	1.76	2.27	3.28	6.52
25		9.9	4.72	4.24	2.71	6.31	5.30	4.47	8.46	1.48	1.76	2.40	3.06	6.45
30		9.8	4.70	4.20	2.67	6.39	5.20	4.62	8.26	1.44	2.00	2.58	2.89	6.35
35		9.7	4.54	4.04	2.48	6.31	5.18	4.38	8.02	1.36	1.78	2.80	2.66	6.28
40		9.6	4.43	3.88	2.30	6.17	5.10	4.34	8.10	1.16	1.70	2.95	2.49	6.10
45		9.5	4.40	3.76	2.23	6.24	5.10	4.40	7.90	1.08	1.74	3.08	2.30	5.81
50		9.4	4.13	3.66	2.18	6.17	4.94	4.40	7.80	1.12	1.70	3.21	2.15	5.54
55		9.3	4.07	3.42	2.02	6.09	4.90	4.28	7.80	1.20	1.52	3.36	1.81	5.33
17 0	5.7	9.3	4.04	3.36	1.95	5.64	4.90	4.22	7.80	1.04	1.55	3.50	1.81	5.15
5		9.2	3.93	3.24	1.89	5.57	4.68	4.20	7.74	1.20	1.48	3.58	1.68	4.93
10		9.1	3.88	3.20	1.92	5.50	4.52	4.20	7.64	1.20	1.48	3.58	1.39	4.71
15		8.8	3.68	3.14	1.79	5.64	4.52	4.20	7.62	1.20	1.48	3.58	1.42	4.51
20		8.6	3.76	2.84	1.47	5.42	4.50	4.02	7.54	1.20	1.38	3.58	1.34	4.40
25		8.5	3.60	2.64	1.32	5.12	4.20	3.86	7.32	1.16	1.36	3.58	1.25	4.27
30		8.5	3.70	2.70	1.37	5.42	4.34	3.92	7.02	1.00	1.52	3.66	1.19	4.11

Greenwich mean astr. t. May 17, 1901.	15. Karang Sago, East D_0 +	16. Sawah Loento, East 0° 50′ +	17. Batavia, East D_0 *minus*	18. Manila, East 0° 50′ +	19. Zi-ka-wei, West D_0 +	20. Melbourne, East 8° 20′ +	21. Christchurch, East D_0 +	22. Sitka, East 29° 30′ +	23. Contadero, East 7° 30′ +	24. Austin, East 8° 05′ +	25. Baldwin (E3), East 8° 20′ +	25a. Baldwin (M3), East 8° 20′ +	26. Little Rock, East 6° 30′ +	27. Toronto, West 5° 20′ +	28. Gaithersburg, West 6° 25′ +	29. Cheltenham (M8), West 5° +	29a. Cheltenham AI, West 5° +	29b. Cheltenham (EI5), West 5° +	29c. Cheltenham AT, West 5° +	29d. Cheltenham ET4, West 5° +	30. Porto Rico, West 1° 10′ +	Greenwich mean astr. t. May 17, 1901.
h m	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	h m
14 0			2.22	1.8		4.62		2.10		4.18	6.74	4.39	4.84	9.7	5.28	4.61					1.96	14 0
5				1.80		4.78		2.14		4.41	6.74	4.39	5.04	9.5	5.28	4.59	4.51	4.82	4.53	4.51	1.96	5
10				1.76		4.82	8.91	2.26		4.69	6.74	4.52	4.86	9.5	5.31	4.56	4.52	4.94	4.58	4.48	1.99	10
15				1.73		5.08	8.95	2.35		4.65	6.68	4.39	4.94	9.6	5.42	4.52	4.54	5.03	4.60	4.51	2.14	15
20				1.70		5.30	8.97	2.35		4.64	6.64	4.39	5.04	9.6	5.39	4.45	4.52	5.05	4.60	4.60	2.14	20
25				1.66		5.52	8.93	2.35		4.73	6.70	4.42	5.06	9.5	5.10	4.40	4.48	4.91	4.53	4.46	2.29	25
30			2.45	1.63		5.68	8.95	2.39		4.74	6.86	4.60	5.12	9.1	5.02	4.41	4.46	4.73	4.46	4.38	2.14	30
35				1.58		5.85	8.87	2.47		4.61	6.96	4.56	4.96	9.2	5.06	4.40	4.44	4.66	4.44	4.41	2.14	35
40				1.54		6.03	8.80	2.51		4.64	6.90	4.39	4.82	9.4	5.13	4.39	4.47	4.74	4.51	4.46	2.14	40
45				1.48		6.23	8.73	2.59		4.55	6.76	4.34	4.90	9.4	5.13	4.43	4.48	4.81	4.51	4.45	2.10	45
50				1.41		6.55	8.66	2.63	2.20	4.70	6.74	4.25	4.80	9.5	5.10	4.45	4.47	4.88	4.49	4.40	1.96	50
55				1.34		6.73	8.66	2.72	2.20	4.61	6.84	4.32	4.80	9.4	5.10	4.45	4.46	4.84	4.49	4.38	2.10	55
15 0			2.79	1.26		6.98	8.60	2.72	2.09	4.53	6.88	4.32	4.72	9.4	5.06	4.48	4.45	4.68	4.49	4.31	2.14	15 0
5		2.66		1.21		7.18	8.59	2.76	2.13	4.62	6.90	4.41	4.80	9.0	5.06	4.41	4.44	4.60	4.46	4.28	2.18	5
10		2.70		1.17	1.36	7.28	8.50	2.84	2.20	4.45	6.84	4.41	4.68	9.4	5.13	4.38	4.47	4.63	4.44	4.35	2.32	10
15		2.66		1.16	1.24	7.45	8.42	2.88	2.38	4.40	6.78	4.39	4.78	9.4	5.21	4.32	4.47	4.65	4.40	4.38	2.32	15
20		2.54		1.15	1.17	7.50	8.10	2.96	2.35	4.62	6.80	4.29	4.72	9.2	5.17	4.27	4.45	4.62	4.38	4.35	2.47	20
25		2.58		1.11	1.23	7.65	8.08	2.96	2.38	4.62	6.84	4.39	4.72	9.2	5.17	4.21	4.44	4.58	4.34	4.30	2.51	25
30		2.66	2.68	1.09	1.17	7.68	7.55	3.00	2.38	4.69	6.80	4.39	4.84	9.4	5.13	4.18	4.44	4.54	4.40	4.31	2.51	30
35		2.66		1.07	1.17	7.73	7.60	3.12	2.50	4.78	6.84	4.44	4.80	9.4	5.13	4.20	4.46	4.53	4.21	4.26	2.51	35
40		2.66		1.03	1.17	7.83	7.65	3.13	2.42	4.76	6.94	4.42	4.98	9.2	5.06	4.17	4.39	4.48	4.03	4.23	2.51	40
45		2.66		0.98	1.17	7.83	7.65	3.00	2.50	4.65	6.88	4.39	4.94	8.9	5.10	4.13	4.18	4.37	3.99	4.16	2.32	45
50		2.69		0.92	1.17	7.92	7.52	3.12	2.42	4.45	6.84	4.47	4.86	8.9	4.88	4.11	4.11	4.30	3.91	4.05	2.32	50
55		2.78		0.85	1.12	8.03	7.40	3.20	2.57	4.47	6.84	4.48	4.76	9.0	4.88	4.05	4.04	4.25	3.87	4.02	2.32	55
16 0		2.93	2.91	0.81	1.07	8.05	7.38	3.24	2.69	4.48	6.86	4.47	4.94	8.9	4.73	3.95	3.91	4.12	3.80	3.95	2.25	16 0
5		3.16		0.76	0.91	8.03	7.31	3.26	2.65	4.65	7.04	4.69	4.98	8.7	4.66	3.89	3.79	4.01	3.80	3.85	2.14	5
10		3.31		0.72	0.80	7.92	7.29	3.16	2.76	4.59	7.14	4.92	4.86	8.7	4.62	3.86	3.73	3.97	3.82	3.82	2.21	10
15	1.26	2.99		0.68	0.80	7.88	7.25	3.37	2.76	4.65	7.14	4.82	5.08	8.7	4.62	3.82	3.72	3.90	3.82	3.79	2.14	15
20	1.36	2.81		0.69	0.80	7.83	7.20	3.49	2.76	4.68	7.06	4.71	5.06	8.7	4.59	3.79	3.74	3.91	3.82	3.77	2.14	20
25	1.38	2.75	2.71	0.73	0.69	7.77	7.18	3.53	2.80	4.69	7.04	4.67	4.74	8.9	4.55	3.79	3.74	3.94	3.82	3.84	2.14	25
30	1.38	2.75	2.63	0.77	0.64	7.73	7.13	3.38	2.72	4.70	7.10	4.78	4.84	8.6	4.55	3.82	3.72	3.91	3.78	3.81	2.14	30
35	1.38	2.72	2.45	0.84	0.64	7.73	7.09	3.20	2.69	4.76	7.04	4.61	4.84	8.5	4.55	3.80	3.72	3.85	3.80	3.79	2.14	35
40	1.36	2.81	2.33	0.89	0.75	7.68	7.02	3.20	2.72	4.82	7.04	4.56	5.00	8.7	4.52	3.78	3.71	3.79	3.78	3.74	2.25	40
45	1.28	3.28	2.24	0.93	0.80	7.62	6.88	3.24	2.84	4.72	7.04	4.55	4.94	8.6	4.52	3.78	3.70	3.84	3.76	3.75	2.32	45
50	1.25	3.46	2.08	1.01	0.80	7.48	6.80	3.37	3.10	4.89	7.04	4.53	4.94	8.9	4.59	3.79	3.72	3.88	3.80	3.84	2.32	50
55	1.22	3.51	1.98	1.07	0.80	7.45	6.57	3.52	3.13	4.95	7.06	4.66	4.92	8.6	4.62	3.79	3.70	3.81	3.78	3.77	2.32	55
17 0	1.11	3.49	1.97	1.12	0.96	7.25	6.55	3.70	3.21	4.82	7.06	4.57	4.86	8.5	4.44	3.72	3.70	3.84	3.83	3.72	2.32	17 0
5	1.05	3.57	1.93	1.19	0.91	7.17	6.48	3.60	3.17	4.74	7.08	4.50	4.78	8.5	4.44	3.78	3.71	3.85	3.80	3.75	2.32	5
10	1.05	3.57	1.84	1.23	0.64	7.05	6.17	3.53	3.17	4.81	7.06	4.51	4.84	8.3	4.41	3.84	3.70	3.77	3.76	3.77	2.51	10
15	1.03	3.57	1.76	1.23	0.64	6.90	5.98	3.41	3.28	4.72	7.14	4.72	4.78	8.3	4.41	3.87	3.69	3.73	3.72	3.70	2.51	15
20	1.00	3.51	1.69	1.27	0.64	6.87	5.72	3.26	3.28	4.81	7.08	4.77	4.84	8.3	4.37	3.85	3.69	3.71	3.70	3.67	2.51	20
25	1.00	3.43	1.62	1.30	0.64	6.67	5.58	3.04	3.25	4.84	7.14	4.76	4.66	8.5	4.37	3.81	3.69	3.73	3.59	3.67	2.47	25
30	1.05	3.43	1.59	1.34	0.64	6.63	5.49	2.96	3.28	4.90	7.14	4.71	4.84	8.2	4.33	3.69	3.68	3.72	3.46	3.60	2.32	30

Digitized by Google

TABLE II.—Concluded.

Greenwich mean astr. t. May 17, 1901. h m	1. Stonyhurst, West 18° +	2. Val Joyeux, West 15° +	3. Flushing, West 14° 40′ +	4. de Bilt, West 13° 40′ +	5. Groningen, West D_0 +	6. Wilhelmshaven, West 12° 15′ +	7. Munich, West 10° 15′ +	8. Potsdam, West 9° 45′ +	9. Pola, West 9° 10′ +	10. Bucharest, West 4° 08′ +	11. Pawlowsk, East 0° 30′ +	12. Mauritius, West D_0 +	13. Colaba, East 0° 20′ +	14. Dehra Dûn, East 2° 40′ +	15. Karang Sago, East D_0 +
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
17 30		8.5	3.70	2.70	1.37	5.42	4.34	3.92	7.02	1.00	1.52	3.66	1.19	4.11	1.05
35		8.4	3.73	2.72	1.35	5.35	4.28	3.94	6.90	1.00	1.62	3.70	1.17	4.08	0.97
40		8.3	3.66	2.60	1.28	5.20	4.08	3.66	6.90	1.00	1.54	3.70	1.08	3.96	0.88
45		8.2	3.60	2.60	1.26	4.90	3.78	3.58	6.96	1.08	1.66	3.70	1.06	3.67	0.82
50		8.1	3.70	2.64	1.27	4.98	3.78	3.58	6.90	1.20	1.74	3.70	0.97	3.57	0.94
55		8.0	3.68	2.48	1.10	4.83	3.74	5.46	6.80	1.24	1.74	3.70	0.97	3.51	1.12
18 0	4.2	7.9	3.66	2.36	1.02	4.75	3.72	3.88	6.80	1.36	1.78	3.70	0.85	3.44	1.25
5		7.9	3.51	2.22	0.92	4.83	3.66	3.80	6.68	1.40	1.82	3.70	0.74	3.36	1.35
10		7.8	3.51	2.20	0.94	4.68	3.76	3.84	6.60	1.44	2.12	3.62	0.66	3.24	1.47
15		7.7	3.61	2.13	0.90	4.83	3.66	3.92	6.52	1.60	2.26	3.47	0.63	3.15	1.56
20		7.4	3.42	2.04	0.72	4.75	3.60	3.79	6.50	1.60	2.30	3.32	0.51	3.08	1.68
25		7.3	3.41	1.92	0.62	4.53	3.66	3.71	6.50	1.68	2.36	3.25	0.43	3.02	1.71
30		7.1	3.41	1.70	0.59	4.53	3.52	3.67	6.50	1.80	2.54	3.14	0.29	3.07	1.79
35		7.0	3.24	1.68	0.58	4.53	3.38	3.71	6.44	1.80	2.72	2.91	0.20	3.17	1.88
40		6.9	3.04	1.60	0.57	4.53	5.48	3.78	6.40	1.84	2.84	2.73	0.29	3.27	1.94
45		6.7	2.89	1.58	0.41	4.45	3.52	3.75	6.48	2.12	3.02	2.64	0.23	3.22	2.01
50		6.6	2.83	1.50	0.37	4.38	3.34	3.74	6.50	2.20	3.18	2.49	0.17	3.08	2.04
55		6.5	2.71	1.46	0.41	4.45	3.42	3.93	6.50	2.32	3.34	2.29	0.17	3.15	2.09
19 0	3.2	6.4	2.58	1.34	0.37	4.53	3.62	3.91	6.50	2.76	3.49	2.01	0.15	2.99	2.07
5		6.4	2.49	1.24	0.37	4.60	3.80	3.98	6.56	3.12	3.70	1.76	0.17	3.15	1.97
10		6.4	2.48	1.24	0.46	4.60	3.86	4.09	6.60	3.20	3.84	1.59	0.21	3.18	1.93
15		6.3	2.34	1.22	0.48	4.68	4.12	4.17	6.54	3.28	3.98	1.46	0.17	3.15	1.91
20		6.2	2.22	1.28	0.39	4.68	4.52	[illegible]	6.62	3.68	4.18	1.32	0.17	3.14	1.87
25		6.1	2.15	1.30	0.50	4.75	4.44	4.28	6.78	4.04	4.32	1.18	0.23	3.12	1.79
30		6.1	2.11	1.40	0.53	4.68	4.46	4.37	6.82	4.36	4.62	1.09	0.26	3.10	1.66
35		6.0	2.21	1.44	0.58	4.75	4.60	4.50	6.96	4.44	4.82	1.00	0.29	3.04	1.57
40		6.1	2.50	1.56	0.73	4.98	4.64	4.70	7.00	4.60	5.00	0.90	0.29	3.07	1.57
45		6.0	2.37	1.58	0.73	4.98	4.76	4.80	7.02	4.80	5.20	0.79	0.32	3.02	1.55
50		5.7	2.34	1.50	0.71	5.05	4.82	4.90	7.10	4.96	5.32	0.68	0.29	3.08	1.49
55		5.7	2.27	1.58	0.82	5.35	4.98	5.06	7.24	5.04	5.56	0.59	0.32	3.12	1.26
20 0	2.7	5.7	2.30	1.66	0.92	5.42	5.20	5.29	7.40	5.24	5.88	0.50	0.34	2.93	1.26
5		5.8	2.40	1.80	1.03	5.50	5.32	5.46	7.56	5.44	6.16		0.40	2.99	1.41
10		5.8	2.60	1.98	1.10	5.57	5.40	5.58	7.74	5.72	6.34		0.51	3.12	1.53
15		6.0	2.74	2.10	1.18	5.64	5.60	5.70	7.82	5.80	6.62		0.51	3.16	1.60
20		6.1	2.52	2.10	1.22	5.64	5.66	5.75	7.96	5.64	6.86		0.51	3.13	1.64
25		6.2	2.97	2.24	1.41	5.72	5.82	5.88	8.00	6.00	7.14		0.63	3.20	1.69
30		6.3	3.18	2.50	1.63	6.09	6.10	6.00	8.16	6.16	7.36		0.63	3.33	1.71
35		6.3	3.48	2.72	1.91	6.17	6.34	6.17	8.26	6.32	7.70		0.68	3.29	1.71
40		6.5	3.96	3.04	2.06	6.24	6.52	6.23	8.34	6.52	7.94		0.74	3.60	1.60
45		6.7	4.15	3.32	2.22	6.31	6.70	6.43	8.50	6.76	8.22		0.80	3.56	1.60
50		6.8	4.28	3.60	2.54	6.61	6.80	6.59	8.66	6.92	8.50		0.83	3.78	1.52
55		6.9	4.38	3.86	2.80	6.84	6.90	6.78	8.84	7.32	8.78		0.91	3.87	1.34
21 0	3.7	6.9				7.06		7.03					0.97		1.20

Greenwich mean astr. t. May 17, 1901. h m	16. Sawah Loento, East 0° 50′ +	17. Batavia, East D_0 *minus*	18. Manila, East 0° 50′ +	19. Zi-ka-wei, West D_0 +	20. Melbourne, East 8° 20′ +	21. Christchurch, East D_0 +	22. Sitka, East 29° 30′ +	23. Contadero, East 7° 30′ +	24. Austin, East 8° 05′ +	25. Baldwin (E3), East 8° 20′ +	25a. Baldwin (M3), East 8° 20′ +	26. Little Rock, East 6° 30′ +	27. Toronto, West 5° 20′ +	28. Gaithersburg, West 6° 25′ +	29. Cheltenham (M8), West 5° +	29a. Cheltenham (AI), West 5° +	29b. Cheltenham (EI5), West 5° +	29c. Cheltenham (AT), West 5° +	29d. Cheltenham (ET4), West 5° +	30. Porto Rico, West 1° 10′ +
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
17 30	3.43	1.59	1.34	0.64	6.63	5.49	2.96	3.28	4.90	7.14	4.71	4.84	8.2	4.33	3.69	3.68	3.72	3.46	3.60	2.32
35	3.46	1.59	1.40	0.80	6.62	5.49	2.96	3.21	4.95	7.22	4.78	4.82	8.1	4.33	3.62	3.66	3.63	3.61	3.57	2.25
40	3.34	1.59	1.45	0.96	6.55	5.49	2.96	3.36	4.74	7.18	5.00	4.72	8.2	4.30	3.70	3.66	3.62	3.67	3.54	2.14
45	3.19	1.59	1.49	0.96	6.38	5.44	2.96	3.44	4.77	7.24	4.85	4.84	8.2	4.30	3.68	3.66	3.64	3.68	3.55	1.96
50	3.31	1.59	1.54	1.07	6.38	5.40	3.00	3.25	4.82	7.24	4.67	5.04	8.2	4.26	3.73	3.66	3.58	3.70	3.60	1.96
55	3.51	1.56	1.58	1.01	6.30	5.40	3.08	3.32	4.89	7.24	4.63	5.12	8.2	4.26	3.81	3.67	3.63	3.74	3.59	1.96
18 0	3.72	1.56	1.63	0.96	6.15	5.40	3.12	3.32	4.97	7.24	4.68	5.08	8.2	4.23	3.80	3.69	3.66	3.76	3.60	1.96
5	3.78	1.47	1.70	1.07	6.00	5.40	3.20	3.25	4.89	7.24	4.81	5.28	8.2	4.33	3.74	3.69	3.71	3.76	3.62	2.21
10	3.87	1.40	1.74	1.12	5.88	5.40	3.24	3.28	4.81	7.34	4.85	5.26	8.3	4.37	3.77	3.69	3.67	3.76	3.65	2.43
15	3.98	1.28	1.78	1.07	5.68	5.40	3.29	3.36	4.88	7.30	4.91	5.10	8.5	4.37	3.79	3.69	3.68	3.61	3.67	2.25
20	3.93	1.25	1.84	0.96	5.45	5.40	3.20	3.40	4.93	7.24	5.15	5.06	8.2	4.33	3.74	3.67	3.70	3.61	3.64	2.18
25	3.93	1.23	1.89	0.96	5.28	5.40	3.16	3.32	4.93	7.42	5.15	5.10	8.2	4.19	3.70	3.65	3.66	3.61	3.59	1.99
30	3.90	1.13	1.93	0.96	5.17	5.36	3.12	3.28	4.95	7.50	5.09	5.10	8.2	4.12	3.80	3.63	3.60	3.55	3.54	1.96
35	4.02	0.95	1.90	0.96	5.08	5.33	3.24	3.36	5.02	7.44	4.95	5.04	8.3	4.12	3.74	3.64	3.40	3.57	3.52	1.99
40	4.10	0.86	1.84	0.96	4.87	5.35	3.29	3.25	5.09	7.36	4.92	4.94	8.5	4.12	3.66	3.62	3.31	3.48	3.52	1.96
45	4.10	0.84	1.76	0.91	4.78	5.36	3.12	3.17	5.10	7.42	4.82	5.16	8.3	4.0[illegible]	3.65	3.60	3.33	3.42	3.52	1.96
50	4.07	0.73	1.66	0.91	4.70	5.40	2.84	3.21	5.11	7.54	4.89	5.32	8.2	4.08	3.52	3.53	3.24	3.35	3.49	1.96
55	4.01	0.67	1.55	0.96	4.67	5.35	2.84	3.25	5.17	7.60	4.95	5.02	8.1	4.04	3.52	3.43	3.12	3.31	3.44	1.96
19 0	4.04	0.60	1.50	0.96	4.65	5.40	2.80	3.25	5.23	7.64	5.01	4.86	8.0	4.01	3.54	3.39	3.05	3.31	3.35	1.9[illegible]
5	3.90	0.53	1.44	0.96	4.58	5.40	2.72	3.32	5.11	7.60	4.99	5.18	8.2	4.01	3.56	3.44	3.08	3.31	3.42	1.96
10	3.78	0.51	1.37	1.01	4.58	5.40	2.76	3.25	5.22	7.54	4.81	5.32	8.2	3.97	3.51	3.44	3.10	3.35	3.44	1.96
15	3.81	0.51	1.32	1.12	4.53	5.40	2.80	3.17	5.28	7.44	4.90	5.28	8.1	3.97	3.39	3.40	3.08	3.37	3.39	2.10
20	3.90	0.48	1.26	1.12	4.53	5.40	2.76	3.10	5.23	7.50	4.89	5.22	8.1	3.80	3.32	3.33	3.00	3.37	3.34	2.03
25	3.90		1.23	1.17	4.42	5.38	2.80	3.17	5.28	7.54	4.82	5.26	8.[illegible]	3.79	3.30	3.29	2.95	3.33	3.35	2.10
30	3.86	0.47	1.23	1.23	4.43	5.38	2.72	3.36	5.26	7.54	4.75	5.26	8.2	3.90	3.29	3.29	2.97	3.35	3.37	2.07
35			1.23	1.12	4.42	5.40	2.68	3.36	5.42	7.56	4.84	5.20	8.2	3.72	3.24	3.28	3.05	3.26	3.34	1.9
40			1.23	1.12	4.42	5.40	2.59	3.51	5.42	7.64	4.96	5.40	7.8	3.68	3.24	3.21	3.02	3.20	3.28	1.96
45			1.23	1.12	4.35	5.40	2.59	3.40	5.36	7.64	5.04	5.30	8.0	3.68	3.23	3.16	2.96	3.20	3.23	1.96
50			1.23	1.12	4.35	5.36	2.59	3.36	[illegible]	7.64	5.32	5.20	7.6	3.64	2.99	3.10	2.88	3.20	3.21	1.96
55			1.23	1.12	4.30	5.31	2.63	3.40	5.48	7.64	5.25	5.30	8.0	3.64	2.97	3.17	2.94	3.20	3.18	1.96
20 0		0.51	1.23	1.12	4.27	5.22	2.70	3.5[illegible]	5.50	7.62	5.17	5.30	8.0	3.61	3.07	3.23	3.02	3.21	3.23	1.96
5			1.23	1.12	4.27	5.22	2.84	3.73	5.44	7.62	5.27	5.30	7.8	3.64	3.10	3.24	3.03	3.20	3.26	1.96
10			1.23	1.12	4.27	5.15	2.84	3.73	5.47	7.62	5.31	5.20	7.8	3.68	2.97	3.21	3.00	3.20	3.26	1.96
15			1.23	1.12	4.23	5.08	2.76	3.62	5.50	7.54	5.30	5.28	7.7	3.68	3.08	3.20	2.97	3.20	3.26	1.96
20			1.23	1.12	4.30	5.04	2.55	3.55	5.46	7.56	5.31	5.20	7.7	3.57	3.19	3.14	2.92	3.20	3.23	1.96
25			1.23	1.12	4.32	5.04	2.47	3.51	5.56	7.64	5.32	5.24	7.6	3.53	3.08	3.02	2.84	3.20	3.18	1.96
30		0.73	1.24	1.12	4.27	5.04	2.47	3.43	5.55	7.72	5.34	5.38	7.6	3.50	2.91	2.92	2.72	3.12	3.09	1.96
35			1.30	1.12	4.27	5.11	2.51	3.73	5.58	7.84	5.34	5.46	7.6	3.50	2.82	2.90	2.69	2.93	2.96	1.96
40			1.38	1.12	4.23	5.17	2.59		5.63	7.80	5.35	5.42	7.6	3.3[illegible]	2.80	2.90	2.58	2.93	2.91	1.96
45			1.48	1.15	4.23	5.15	2.50		5.64	7.84	5.37	5.26	7.6	3.28	2.80	2.89	2.50	2.97	2.88	1.96
50			1.51	1.28	4.27	5.15	2.63		5.69	7.84	5.44	5.20	7.6	3.25	2.64	2.87	2.50	2.93	2.86	1.96
55			1.51	1.28	4.27	5.15	2.76		5.75	7.92	5.45	5.26	7.3	3.17	2.54	2.85	2.49	2.84	2.93	1.96
21 0		0.85	1.5	1.28	4.23		2.84		5.76	7.94	5.44	5.34	7.3	3.10						1.96

TABLE III. Results of the horizontal intensity observations made on May 17, 1901, from 14h to 21h, Greenwich mean astronomical time.

Greenwich mean astronomical time.	1. Stonyhurst, 17369γ+	2. Val Joyeux, 16603γ+	4. de Bilt, 18569γ+	5. Groningen, Ho+ 18119γ+	6. Wilhelmshaven, Ho+ 18119γ+	7. Munich, 20609γ+	8. Potsdam, 18869γ+	9. Pola, 22209γ+	11. Pawlowsk, 16369γ+	12. Mauritius, Ho+ 37449γ+	13. Colaba, 33509γ+	14. Dehra Dun, Ho+ 33509γ+	15. Karang Sago, Ho+	17. Batavia, Ho+ 38109γ+	18. Manila, 38109γ+	19. Zi-ka-wei, Ho+	20. Melbourne, 23369γ+	24. Austin, 28609γ+	27. Toronto, 16499γ+	29a. Cheltenham (AI), 20209γ+	29c. Cheltenham (AI), 20209γ+	29d. Cheltenham (ET), 20209γ+
h m	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
14 0	75	79	64.5						40.	8.6	00.1	55.2		21.1			20.1	58.4	17.6			
5		79	64.5			37.8		24.0	40.0	8.7	00.9				53.8		19.9	59.2	18.1	18.6	18.9	21.0
10		79	64.2		43.6	37.0		24.0	40.0	8.9	01.3				54.0		19.6	57.8	17.2	18.4	18.8	20.7
15		80	64.3		43.5	38.0		24.0	40.0	9.1	02.5	54.8			54.0		19.4	56.8	17.2	18.4	18.9	20.7
20		80	64.8		44.4	38.0		24.0	40.0	9.4	04.2				55.2		19.4	57.1	17.2	19.0	19.6	21.3
25		80	65.9	30.8	44.6	38.6		24.0	40.2	9.3	05.7				56.5		19.4	58.8	18.5	20.2	20.4	21.8
30		79	66.0	30.8	44.0	37.8		24.0	40.0	9.6	07.2	55.2		26.9	57.8		19.1	58.6	19.4	20.4	20.9	22.5
35		79.5	64.9	30.2	42.7	37.2		24.0	40.0	9.9	08.8				59.0		19.1	57.9	18.5	20.6	21.0	23.0
40		80	65.4	30.8	43.3	38.0	67.2	24.0	40.0	10.3	10.3				59.0		19.4	58.4	19.4	20.6	20.9	23.1
45		80	66.1	31.7	43.5	37.2	68.0	24.0	40.0	10.5	11.6	55.2			59.5		19.6	57.9	18.1	20.3	20.7	22.6
50		80	66.0	31.7	44.4	37.4	68.2	24.0	40.0	11.3	13.0				60.0		19.6	58.0	17.6	20.5	21.0	22.6
55		81	65.5	31.5	43.7	37.6	67.9	24.0	40.2	11.5	13.9				60.0		19.4	59.0	18.5	20.8	21.3	22.9
15 0	76	81	66.9	31.5	44.9	39.0	68.6	24.8	40.5	11.9	15.1	55.6		30.1	60.0		20.1	51.0	19.0	20.7	21.3	23.3
5		81	66.7	32.3	44.2	39.0	68.4	25.0	40.2	12.2	16.4				59.8		19.9	58.2	19.0	20.4	20.9	23.1
10		81	66.4	32.3	44.0	39.6	68.4	25.4	41.0	12.6	19.1				59.2	76.1	20.1	58.0	18.1	20.2	20.7	22.7
15		81	67.1	32.8	44.5	39.2	68.6	26.0	40.4	12.6	19.1	55.2			59.0	77.0	20.4	57.8	19.4	20.3	20.7	22.9
20		81	67.1	32.9	43.6	39.8	68.6	26.0	40.8	12.8	21.4				59.0	77.4	20.9	59.1	19.0	20.3	20.7	23.0
25		81	67.0	32.8	44.1	40.6	68.6	26.0	40.2	12.8	22.2				59.0	77.3	20.9	58.6	18.5	20.1	20.2	22.8
30		80	66.7	32.5	43.9	40.6	68.5	26.0	40.0	13.0	23.3	56.4		31.7	59.0	77.7	21.2	58.8	18.5	20.3	21.0	22.6
35		79.5	66.0	31.9	42.9	39.0	68.1	26.0	40.0	13.2	24.3				58.0	76.8	21.5	59.1	20.8	20.6	20.7	23.2
40		79.5	65.3	31.6	42.7	38.6	68.0	25.6	40.0	13.4	25.1				57.0	76.5	21.5	57.9	18.5	19.9	20.2	22.7
45		80	65.2	32.2	43.5	39.4	68.6	24.8	39.6	13.6	26.3	60.0			57.0	77.2	21.7	57.1	17.6	19.8	20.5	22.2
50		81	65.6	32.5	43.6	39.8	68.5	24.6	38.6	13.5	28.5				56.6	77.5	21.7	58.3	18.7	19.5	19.6	22.4
55		81	66.0	32.6	43.5	39.0	68.6	24.4	38.2	12.7	28.8				56.8	77.4	22.0	57.6	17.6	18.5	19.3	21.9
16 0	76	81	67.8	33.5	44.8	40.0	69.1	25.0	38.6	12.5	30.6	65.2		30.0	58.4	78.7	23.0	57.6	18.5	19.7	20.9	22.3
5		81	68.0	33.5	45.1	39.8	69.2	25.0	38.0	13.4	32.8				58.5	79.6	23.6	58.7	20.3	21.4	21.6	23.5
10		81	68.0	33.7	45.2	39.0	68.9	25.4	37.8	13.9	33.9				57.0	79.3	24.1	59.3	19.9	21.0	21.0	23.7
15		81	67.9	33.1	44.0	38.0	68.3	26.0	37.0	14.0	34.4	67.2	39.1		55.0	78.6	23.8	58.8	19.0	20.3	20.6	23.1
20		81	68.0	32.7	44.1	37.8	68.0	26.0	36.4	15.5	34.7		37.9		54.0	77.7	23.8	59.2	19.0	19.8	20.0	22.5
25		80.5	67.7	32.4	43.5	37.0	67.3	25.0	36.2	16.0	35.1		36.6	28.8	53.5	76.1	23.8	58.6	18.7	19.3	19.5	22.3
30		81	67.7	32.4	43.0	37.0	67.0	24.8	35.2	16.3	35.4	71.2	35.1	27.8	53.0	76.4	23.8	58.8	17.6	19.1	19.9	22.2
35		81	68.2	32.4	43.3	37.8	66.7	24.0	35.0	16.8	36.4		34.8	27.6	53.0	76.3	24.6	59.4	18.5	19.9	20.6	22.7
40		81	68.0	32.3	43.1	38.0	66.2	24.0	34.6	17.1	37.4		34.0	26.5	52.2	76.0	24.9	59.8	19.0	20.2	20.3	23.1
45		80	67.4	31.7	42.8	37.0	66.3	24.0	33.8	17.0	37.4	70.8	33.0	24.7	50.8	75.8	25.1	59.8	18.5	19.5	19.7	22.8
50		79	66.8	30.9	41.3	36.2	64.8	24.0	33.0	17.9	37.4		31.8	22.8	49.8	75.9	25.1	59.6	18.5	19.4	19.9	22.3
55		79	65.9	30.4	41.0	36.0	64.1	23.6	32.2	18.1	38.4		31.4	21.9	49.2	75.7	25.1	60.0	19.0	19.4	20.0	22.5
17 0	75	79	64.9	29.9	40.5	36.0	63.4	23.0	31.8	18.2	36.0	70.0	30.6	20.1	50.0	74.4	25.4	59.4	19.0	19.1	19.7	22.4
10		79	64.1	29.4	39.6	35.2	63.3	22.4	31.0	18.5	36.1		30.5	19.5	49.0	74.2	25.9	59.6	18.1	19.1	19.8	22.5
15		78	63.0	27.9	39.3	35.0	62.3	22.0	30.4	18.7	36.4		29.7	18.3	47.4	75.0	25.7	59.0	18.3	19.1	19.2	22.5
20		78	63.5	27.8	38.8	35.0	61.1	22.0	29.6	18.7	36.0	71.6	28.1	17.3	47.0	73.7	25.7	58.7	17.2	18.6	18.8	21.9
25		77	64.1	27.7	38.8	34.8	61.2	22.0	29.2	19.0	36.2		26.7	16.7	46.4	73.6	25.7	58.4	17.6	18.7	19.1	22.2
25		77	63.6	27.3	38.2	33.6	60.6	21.0	28.8	19.2	36.4		25.7	15.9	46.0	73.6	25.9	59.3	17.6	18.8	19.2	22.3
30		76	63.2	26.9	37.3	33.0	60.0	20.2	27.6	19.3	35.0	74.4	23.8	15.2	46.0	73.1	25.9	59.2	17.6	18.7	19.3	22.2
35		76	63.2	26.4	36.8	32.2	58.8	19.4	27.0	19.5	36.1		23.8	15.0	45.5	73.1	27.0	60.2	17.8	18.6	19.0	22.2
40		76	63.1	25.9	36.5	32.0	58.3	19.0	26.2	19.7	35.9		21.8	14.1	44.4	73.2	27.2	60.3	18.1	18.6	19.1	22.1
45		75	62.9	25.5	36.0	32.0	57.7	18.2	25.0	19.7	35.7	75.6	21.3	13.2	43.5	73.3	28.3	60.5	18.1	18.8	19.7	22.1
50		75	62.1	24.7	35.4	30.8	56.8	18.0	24.0	19.8	35.5		21.8	12.6	42.2	73.4	28.8	61.9	18.5	19.7	20.2	22.6
55		75	60.9	24.2	34.2	30.0	55.9	17.0	23.0	19.9	35.1		22.0	11.2	40.8	73.5	29.4	63.1	19.9	19.8	20.1	23.0
18 0	69	75	60.4	23.8	33.9	28.9	55.5	16.2	22.0	20.3	35.4	76.4	21.9	10.9	40.8	73.5	29.6	63.1	19.9	20.1	20.3	23.2
5		75	59.5	22.8	33.0	28.0	54.3	15.4	22.0	20.6	34.0		21.1	10.3	40.8	73.4	29.6	63.4	19.9	19.5	19.7	23.0
10		74	59.1	22.1	32.2	28.0	53.7	14.0	20.0	20.8	34.2		20.3	9.8	40.2	73.4	29.6	62.4	19.0	18.8	19.1	22.4
15		74	58.6	21.5	31.4	28.0	52.9	13.8	19.0	21.3	33.9	79.6	19.0	9.5	39.5	73.3	29.6	62.8	18.7	18.5	18.9	22.0
20		73	58.2	21.1	30.7	28.0	52.7	12.4	18.2	21.8	33.3		17.9	9.5	38.4	73.3	30.4	63.5	18.7	18.6	18.9	22.1
25		72.5	57.4	20.2	29.5	25.4	51.5	11.6	17.0	22.8	33.2		19.5	9.9	38.0	73.3	30.1	64.3	19.0	19.3	19.7	22.7
30		72	55.9	19.5	27.8	25.0	51.1	10.8	16.2	24.0	32.7	80.4	19.8	10.3	38.8	73.2	30.9	65.5	20.3	20.2	20.5	23.6
35		71	55.5	18.6	26.6	25.0	50.7	10.0	14.8	24.9	31.8		20.0	10.5	39.0	73.2	30.9	66.3	20.3	20.3	20.4	23.9
40		70	55.1	17.8	25.8	25.0	50.3	10.0	14.0	25.4	31.2		20.5	10.2	37.0	73.2	31.2	66.3	19.9	20.2	20.3	23.7
45		69	54.9	17.2	25.3	24.0	49.8	10.0	13.6	26.2	31.1	80.8	20.6	10.4	35.2	73.1	31.5	66.7	20.3	20.3	20.7	24.0
50		69	54.6	16.1	23.8	24.0	48.7	10.0	12.4	27.2	30.8		21.2	10.5	33.4	73.1	31.2	66.9	20.8	20.4	20.9	24.1
55		68	54.1	15.5	23.0	24.0	48.5	9.4	11.2	28.0	30.4		21.7	9.0	31.0	72.8	31.2	67.9	21.2	20.5	21.3	24.4
19 0	61	68	52.6	14.5	22.2	23.0	47.7	9.2	11.5	28.5	29.8	79.6	21.8	10.0	29.0	71.0	31.2	68.1	21.7	20.0	21.4	24.8
5		68	51.6	13.5	21.4	23.4	47.3	9.0	10.8	28.7	29.3		21.3	9.7	27.0	71.3	31.2	68.3	21.9	20.6	20.9	24.6
10		68	50.3	12.3	20.2	23.0	46.2	10.0	10.2	28.5	27.3		21.2	8.9	26.0	70.7	31.2	67.7	20.3	20.2	20.3	23.9
15		68	49.4	11.4	19.1	25.0	45.4	10.0	8.8	29.4	26.7	80.8	21.5	9.6	25.5	70.4	31.2	67.0	20.3	20.3	20.6	24.0
20		68	48.0	10.0	18.3	24.4	44.7	10.0	8.0	30.2	26.5		21.0	8.8	25.0	70.4	30.9	67.8	20.5	20.7	21.2	24.7
25		68	48.0	9.4	17.5	24.4	44.2	10.4	7.6	31.0	26.2		22.2		24.0	70.4	31.2	68.9	22.6	21.3	21.5	25.0
30		68	48.1	9.0	17.0	24.8	44.0	11.2	7.6	31.3	25.8	79.2	22.4	2.7	23.0	70.4	31.5	69.2	22.1	21.2	21.2	25.0
35		68	49.7	7.3	17.0	24.8	43.4	12.0	7.0	31.6	25.4		22.2		22.8	70.4	31.2	69.4	21.2	20.6	20.8	24.7
40		68	45.3	7.4	15.6	24.0	42.5	13.0	6.6	31.5	25.2		21.7		21.8	69.8	30.9	68.5	21.0	20.3	20.6	24.3
45		67	44.5	6.0	14.8	24.0	41.2	13.8	5.0	31.4	22.0	79.2	20.0		20.5	69.5	31.2	68.4	21.2	20.3	20.6	24.2
50		67	44.4	5.0	14.3	24.8	40.8	14.0	4.4	31.4	21.3		20.0		19.4	69.5	31.2	68.7	20.8	20.4	20.8	24.3
55		67	44.5	5.8	13.7	26.0	40.7	14.4	4.0	31.5	20.6		20.5		18.0	69.6	30.9	69.9	21.9	20.7	21.3	24.7
20 0	56	67	44.0	5.0	13.5	26.4	40.7	15.0	4.0	31.2	19.6	78.0	20.0	3.7	16.4	69.1	30.9	69.8	21.7	20.6	21.0	24.6
5		67	44.0	5.7	12.0	26.4	41.0	15.6	4.0		18.0		19.5		16.0	68.8	30.9	69.6	20.8	20.1	20.4	24.0
10		66	44.9	5.4	12.6	27.6	40.7	16.4	3.6		18.1		18.8		16.0	68.3	30.9	69.2	20.8	20.0	20.3	23.8
15		66	45.1	6.0	12.9	28.0	41.3	16.4	3.2		18.1	75.6	18.4		15.5	68.4	31.2	70.2	21.2	20.2	20.5	24.1
20		65.5	45.3	5.2	13.8	28.2	41.8	17.0	3.4		17.7		17.8		14.4	68.6	31.2	70.8	21.2	20.4	20.7	24.5
25		65	45.1	6.2	13.8	29.0	42.2	18.0	3.0		18.0		17.0		14.0	68.8	31.2	70.8	22.6	20.6	21.2	24.9
30		65	44.6	5.0	14.2	29.6	42.4	18.8	2.4		19.1	72.4	16.0	3.3	14.0	68.5	32.0	70.8	21.7	20.8	21.4	25.0
35		65.5	45.1	4.3	15.1	30.2	43.1	19.0	2.4		18.2		14.9		14.0	68.0	31.7	69.9	22.1	20.6	21.1	24.9
40		66	45.0	6.6	15.1	30.6	44.0	19.4	2.2		14.0		13.7		13.6	67.1	31.2	69.2	20.8	20.4	20.6	24.4
45		67	46.2	7.5	15.7	31.4	44.9	20.0	2.4		13.0	70.8	12.0		13.0	66.2	31.2	68.7	20.5	20.4	20.5	24.3
50		67	46.8	8.5	16.4	32.4	45.8	20.6	3.0		12.1		12.0		13.0	65.9	31.2	68.8	20.3	20.4	20.	24.3
55		67.5	47.0	8.6	16.3	32.6	46.2	22.0	3.0		11.0		11.2		13.0	65.3	30.9	68.5	20.1	20.5	20.6	24.5
21 0	58				17.5		47.0				10.0		10.5	12.6			30.9	68.7	20.3			

Digitized by Google

TABLE IV. Results of the vertical intensity observations made on May 17, 1901, from 14h to 21h, Greenwich mean astronomical time.

Greenwich mean time.		2. Val Joyeux, 42100γ+	4. de Bilt, 43400γ+	8. Potsdam, 43300γ+	9. Pola, 38800γ+	11. Pawlowsk, 47000γ+	12. Mauritius, Z_c+	13. Colaba, 14700γ+	17. Batavia, Z_c+	18. Manila, 11000γ+	19. Zi-ka-wei, Z_c+	20. Melbourne, 56200γ+	Cheltenham (A1), 56600γ+	Cheltenham (AT), 56600γ+
h	m	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
14	0	80	99.6			43.	58.5	64.5	12.8			29.8		
	5	80	99.6		44.0	43.0	58.5	64.8		55.0		29.2	82.9	83.2
	10	80	99.6		44.0	43.0	58.5	64.0		54.6		28.1	83.0	83.2
	15	80	99.6		44.0	43.0	58.5	64.0		55.0		27.6	83.1	83.2
	20	80	99.6		44.0	43.0	58.5	63.7		55.2		27.6	83.2	83.3
	25	80	99.6		44.0	43.0	58.5	62.9		55.8		27.6	83.2	83.4
	30	80	99.6		44.0	43.0	58.5	62.1	9.2	56.0		27.0	83.1	83.5
	35	80	99.3		44.0	43.0	58.5	61.6		56.0		24.8	83.0	83.5
	40	80	99.3	97.7	44.0	43.0	58.5	61.3		56.0		24.8	83.1	83.2
	45	80	99.3	97.5	44.0	43.0	58.5	60.8		55.5		24.3	83.1	83.3
	50	80	99.3	97.3	44.0	43.0	58.5	58.9		55.0		23.2	83.0	83.3
	55	80	99.2	97.8	44.0	42.4	58.5	58.1		55.0		23.7	82.9	83.2
15	0	80	99.0	97.8	44.0	42.0	58.5	56.4	6.5	54.6		25.4	82.8	83.2
	5	80	99.0	98.1	44.0	42.0	58.1	56.0		53.5		24.3	82.9	83.2
	10	80	99.3	98.5	44.0	42.0	57.8	55.6		52.4	18.8	22.6	82.9	83.1
	15	80	99.3	98.4	44.0	41.2	57.8	54.8		52.5	18.6	22.1	82.8	83.2
	20	81	99.3	98.5	44.0	41.0	57.8	53.2		53.0	18.2	20.4	82.8	83.1
	25	81	99.3	98.8	45.0	41.0	57.8	52.7		53.0	19.6	19.9	82.8	83.0
	30	81	99.3	99.2	45.0	41.0	57.8	51.6	5.2	53.0	19.8	20.4	82.7	82.9
	35	81	99.3	99.5	45.0	41.0	57.0	50.3		53.0	20.3	19.3	82.5	82.8
	40	82	99.3	99.4	45.0	41.0	57.0	49.2		52.6	19.8	19.3	82.5	82.7
	45	82	99.3	99.2	45.0	41.0	57.0	48.4		53.2	20.7	19.3	82.4	82.7
	50	82	99.3	99.2	45.0	41.0	57.0	47.6		54.4	21.4	19.3	82.3	82.7
	55	82	99.2	99.2	45.0	41.0	56.6	46.8		55.2	21.4	18.2	82.4	82.7
16	0	82	99.0	99.0	45.0	41.0	56.2	46.0	6.0	56.4	22.3	17.7	82.4	82.5
	5	82	99.0	99.2	45.0	41.0	56.2	45.2		57.0	22.5	17.1	82.3	82.4
	10	82.5	99.0	99.5	45'0	40.6	55.8	46.0		57.0	23.4	16.6	82.3	82.4
	15	83	99.3	99.7	45.0	40.0	55.4	45.2		57.2	24.3	16.6	82.3	82.5
	20	83	99.3	99.7	45.0	40.0	55.4	44.4		58.4	24.8	16.6	82.4	82.7
	25	83	99.3	99.7	45.0	40.8	55.0	45.2		59.8	24.3	16.0	82.5	82.7
	30	83	99.3	99.7	45.6	41.0	54.7	43.9	7.6	60.0	24.8	17.7	82.6	82.7
	35	83	99.3	99.7	45.6	41.0	54.7	44.4		60.0	24.3	17.7	82.7	82.8
	40	83	99.2	99.4	45.0	41.0	54.7	43.6	8.0	60.6	25.0	17.7	82.7	82.8
	45	83	99.0	99.2	45.0	40.8	54.7	43.9		61.0	24.8	18.2	82.8	82.8
	50	83	99.0	98.7	45.0	40.0	54.9	43.9	8.0	61.0	24.3	18.2	82.8	82.8
	55	83	99.0	98.4	45.0	40.0	55.2	44.4		61.2	25.0	18.8	82.7	82.7
17	0	83	98.8	98.2	45.0	40.0	55.4	43.9	7.8	61.8	25.0	18.8	82.7	82.7
	5	83	98.4	98.2	45.0	40.0	55.6	42.8		62.5	24.8	19.3	82.7	82.7
	10	83	98.0	98.0	44.4	40.0	56.2	40.3	7.8	63.0	24.3	17.7	82.6	82.6
	15	83	97.7	98.2	45.0	40.0	56.2	40.3		63.2	24.9	18.2	82.4	82.6
	20	83	97.4	98.1	45.0	40.0	56.2	40.3	8.7	64.2	24.5	18.2	82.0	82.1
	25	83	97.1	97.8	45.0	40.0	56.2	40.3		65.2	23.9	18.2	81.8	81.8
	30	83	97.1	97.8	45.0	40.0	56.2	39.5	10.0	66.2	23.0	17.7	81.8	81.8
	35	83	96.8	97.4	45.0	40.0	56.2	39.5		67.0	22.5	17.7	81.7	81.8
	40	83	96.8	97.1	45.0	40.0	56.2	39.9	10.5	67.0	23.2	17.1	81.7	81.8
	45	83	96.8	96.9	45.0	40.0	56.2	38.7		66.5	23.4	16.6	81.8	81.7
	50	84	97.1	96.9	45.0	40.0	56.6	38.7	10.5	66.0	23.9	15.5	81.9	81.8
	55	84	97.1	96.9	45.0	40.0	57 0	38.3		66.0	23.2	15.5	81.9	82.1
18	0	84	97.1	96.7	45.0	40.0	57.2	37.9	11.2	66.2	23.2	16.0	82.0	82.2
	5	84	97.1	96.6	45.0	40.0	57 8	37.1		65.5	23.4	16.0	82.1	82.2
	10	84	97.1	96.5	45.0	40.0	58.0	37.9	12.5	65.4	24.1	14.4	82.3	82.3
	15	84	96.8	96.4	44.2	40.0	58.5	38.7		66.2	24.1	13.8	82.4	82.4
	20	84	96 8	96.4	44.0	40.0	59.3	38.7	13.9	66.8	24.1	14.4	82.5	82.5
	25	84	96.5	96.1	44.0	40.0	59.5	39.5	14.1	67.0	24.1	13.8	82.7	82.7
	30	83	96 4	95.7	43.2	39.2	59.8	40.3	13.7	68.0	24.3	12.7	82.8	82.8
	35	83	96.0	95.1	43.0	39.0	60.8	40.3		69.0	25.0	13.8	82.9	82.9
	40	82	95.6	94.2	42.6	39.0	62.4	42.0	12.0	69.0	25.2	13.8	82.9	83.0
	45	81	95.3	93.5	42.0	38.6	63.1	43.9		69.0	26.1	12.2	83.0	83.1
	50	80.5	94.5	93.1	42.0	38.0	63.1	45.2	11.4	69.0	26.8	11.1	83.1	83.2
	55	80	93.5	92.2	41.0	38.0	63.9	46.0		69.0	27.0	11.1	83.3	83.3
19	0	80	93.0	91.4	41.0	37.5	65.0	45.5	10.8	69.2	27.7	10.5	83.4	83.3
	5	79.5	92.4	90.8	40.4	37.0	65.5	46.0		69.8	27.9	10.0	83.5	83.3
	10	78.5	91.4	90.2	38.6	36.8	65.5	47.6	9.1	70.0	28.8	09.4	83.6	83.5
	15	78	90.6	89.9	37.8	36.0	65.5	47.6		70.0	29.5	08.3	83.6	83.6
	20	77	90.0	89.1	37.0	35.6	65.8	47.9	8.4	70.2	29.5	07.2	83.6	83.4
	25	76.5	88.5	88.1	36.6	35.0	66.2	48.4		70.8	29.7	07.2	83.5	83.3
	30	76	87.6	87.1	35.2	35.0	66.2	49.2	8.3	72.0	30.4	06.7	83.4	83.3
	35	75	86.3	86.3	34.4	35.0	66.6	49.5		73.0	30.4	06.7	83.6	83.4
	40	74	84.9	85.2	33.6	34.6	67.8	49.2		73.4	30.4	06.7	83.8	83.4
	45	74	83.5	84.4	32.8	33.6	67.8	49.2		74.0	30.6	06.1	83.8	83.5
	50	72.5	82.8	83.4	32.0	32.6	67.8	48.7		74.0	31.5	05.6	83.7	83.6
	55	71	81.3	82.5	31.0	32.0	67.8	48.7		74.0	32.1	02.8	83.6	83.5
20	0	71	80.2	81.3	30.8	32.0	67.8	49.5	10.0	74.4	32.1	02.8	83.4	83.4
	5	70.5	79.3	80.7	29.4	31.4		50.0		75.0	32.3	01.2	83.4	83.4
	10	70	78.4	80.0	29.0	30.4		50.3		75.2	32.8	02.8	83.3	83.3
	15	69	78.3	79.5	28.8	29.8		50.8		75.8	32.3	02.8	83.1	83.2
	20	69	78.0	78.6	28.0	28.8		50.0		76.0	33.0	01.7	83.0	83.3
	25	68	77.8	78.1	27.6	28.0		50.0		76.0	33.0	01.7	92.9	83.0
	30	68	77.5	77.6	26.8	27.4		48.7	17.0	76.0	33.0	00.6	82.9	82.8
	35	67	77.2	77.3	26.0	27.0		49.2		76.5	33.0	01.2	83.0	82.9
	40	66.5	77.2	76.9	25.0	26.6		48.7		77.0	33.0	01.7	83.0	83.0
	45	66	76.9	76.6	24.2	26.0		49.2		77.0	33.0	01.7	83.0	83.0
	50	66	76.5	76.1	23.4	25.2		49.5		77.0	33.2	02.3	83.0	82.9
	55	64.5	75.8	75.8	22.6	25.0		49.2		77.0	33.9	03.4	83.1	83.0
21	0			75.5				50.0	22.6			02.8		

Digitized by Google

We are now prepared to examine whether any magnetic effect reve itself which might again be attributed to the total solar eclipse. apparent that an investigation of this character which deals with c paratively small quantities, demands searching scrutiny, and, above absolute freedom from bias one way or the other. I have endeavore sift all of the evidence with the utmost care and as though no effect been previously found. I shall attempt to put the results before reader in such a shape that he may form an independent opinion.

All of the results given in Tables II, III, and IV have been plotted cross section paper, arranging the stations generally according to creasing longitude. An inspection of the curves thus obtained sho that, over the entire globe, *during the interval of observation, viz., 17th, 14^h to 21^h, Greenwich mean astronomical time, there was no lar general magnetic disturbance, and that hence the interval was a favora one for the detection of smaller disturbances or variations.* We can, the fore, confine our attention almost exclusively to a consideration of results obtained within or close to the belt of totality.

Magnetic Declination Curves.

Figure 2 gives a graphical representation of the changes in magne declination at the three stations within the totality belt, viz.: Mauriti Sawah Loento, Karang Sago, also at Batavia, about 350 miles sou of the central line of shadow, and at Manila about three times this di tance north of the belt, the maximum obscuration being 0.52, and at thr very distant stations from the totality belt, viz.: Christchurch (Ne Zealand), Zi-ka-wei (China), and Melbourne (Australia).

Beginning with *Mauritius*, near the extreme western extremity of th belt, at which the second contact[1] (the first because of clouds was not o

[1] Extracted from "Total Eclipse of the Sun, 1901, May 18th. Preliminary accou of the observations made at the Royal Alfred Observatory, Pamplemousses, Mauriti By Walter Maunder: Proc. Roy. Soc. Vol. LXIX No. 454. From the same source t following extract is taken:

The weather at eclipse time—i. e. from 6^h 51^m to 9^h 05^m A. M. (local mean time had been by no means promising for the first three weeks after landing, but ha tended to improve later. The morning of May 18th was the first upon which the Su had been entirely free from cloud at the time of totality, 7^h 53^m A. M., and even o that morning first contact was lost by the interposition of a dense bank of cloud which came up from the east soon after sunrise and overtook the Sun. It passe away in a few minutes and the first photograph of the partial phase was taken at minutes after the predicted time for first contact. Light scud continued to pass ove the Sun for about forty minutes more, but got thinner and lighter as totality drew on, and about 2½ or 3 minutes before second contact the entire eastern half of the sky was free from cloud, and remained so until after fourth contact. But though the sky was thus apparently clear there was evidently much moisture in the air, since a Quatre Bornes, 13 miles to the southwest, the total phase was observed in a smar drizzle of fine rain; and at Curepipe, 16 miles to the south, it was entirely lost by thick cloud.

* * * * *

"The darkness during totality to the observers out in the open air was not great, the general illumination being considerably greater than at the full moon. Five observers noting the twilight illumination in the evening after the eclipse, considered it equal to that of midtotality, at the following local times" (Average 5^h 57.6^m).

Digitized by Google

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS.

Digitized by Google

served) occurred on May 18th, at $7^h\ 51^m.7$ local mean time, the third at $7^h\ 55^m.2$ and the fourth at $9^h\ 04^m.7$, the corresponding Greenwich mean astronomical times being May 17th, $16^h\ 01.5^m$, $16^h\ 05.0^m$ and $17^h\ 14.5^m$ respectively, and looking over the curve—the full one—representing the declination observations for the interval 14^h–20^h May 17th, mean astronomical time, we see that the curve shows no marked irregularities. Comparing it with the dotted curve, which represents for the same interval the changes in declination on the average for the entire month of May, 1901, we note the following:

The declination of the north end of the needle being west, it reaches its maximum value in the morning, since Mauritius is in the southern magnetic hemisphere. A minimum of west declination occurs, however, at this station before the regular morning elongation of maximum westerly declination. As compared with the mean monthly curve, the curve of May 18th (l. m. t.) has its summit (the early minimum) considerably flattened and spread over nearly an hour. It would seem as though the steady ascent (decrease of west declination) of the curve suffered an interruption just before the time when the first contact occurred about $15^h\ 01^m$. Another marked departure from the mean monthly curve or normal curve is noticeable about the time of the fourth contact and thereafter, the maximum like the early morning subordinate minimum being again prolonged. The curve of pluses (+ + + +) represents the residuals or departures of the May 18th curve from the normal one, and it will be seen that this curve has first a low point about 26 minutes before the first contact, next a peak 18 minutes before the middle of totality, then a low point again 14½ minutes before the fourth contact; the time from trough to trough of this wave is $2^h\ 25^m$, i. e. about the duration ($2^h\ 14^m$) of the entire eclipse from first to last contact and the total range is about 0.65 minute of arc. For sometime before totality, the north end was deflected towards the east and for sometime thereafter towards the west. After the fourth contact we find the May 18th curve departing steadily more and more from the normal curve, as the result of some cause.

The next station, *Karang Sago*, at which Dr. van Bemmelen of the Batavia magnetic observatory made his magnetic observations, was practically in the central line of the shadow; the duration of totality was $6^m\ 22^s$ and the time from $17^h\ 38^m$ to $17^h\ 44^m$ Greenwich mean astronomical time, May 17th. Figure 3 shows the location of this station as also of Sawah Loento. The full curve of Figure 2 again represents the magnetic declination changes, plotted (*D* being east) so that increasing ordinates signify increasing east declination. Unfortunately, for the reasons stated in van Bemmelen's report, it is not possible to connect the observations made before the time of first contact with those made thereafter. He therefore refrained from publishing them; the figures with which he supplied me subsequently show that the easterly declina-

Digitized by Google

tion beginning at 14 h at first decreased until 14 h 45 m and then increased rapidly up to 16 h 15 m when he changed from the twenty-four-hour cylinder to the six-hour one. As compared with the day before, this increase was a comparatively rapid one. Instead of taking as the normal curve, the mean of van Bemmelen's results from May 9th–17th, contained in his report, for which only the hourly values are, however, given, I have deemed it better to select the curve of the day before (May 17th) for which I have fifteen minute values. This curve, as far as I have

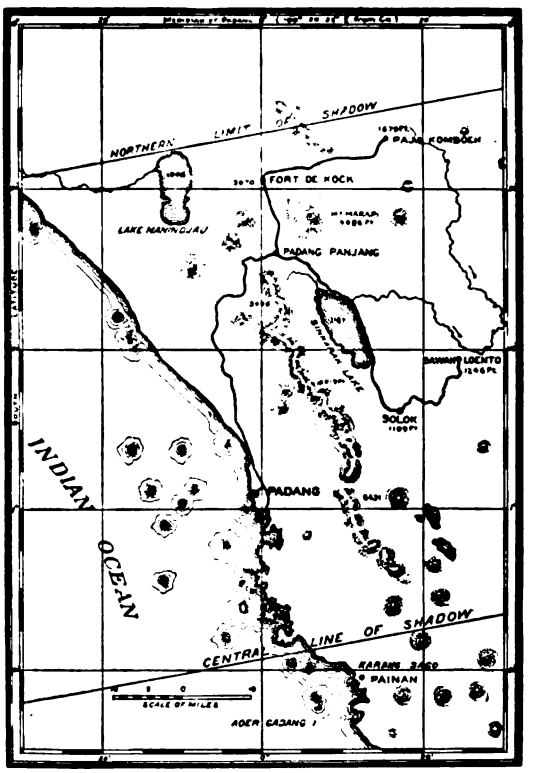


FIGURE 3. Showing location of Karang Sago and Sawah Loento.

been able to determine, appears to have been an undisturbed one, and by selecting this one with which to compare the curve of the day of the eclipse, data are obtained which can be compared directly with those at the neighboring station, Sawah Loento, for which there are declination readings on May 17th and 18th. The curve of pluses (+ + + +) again represents the residuals or departures between the two curves.

Comparing the two curves, May 17th and May 18th, we see no strik-

Digitized by Google

ing dissimilarity between them at first, except that the minimum appears to have occurred somewhat earlier on May 18th than on May 17th which fact, however, is not of itself of sufficient moment, and is of common occurrence However, a *striking* change occurs about thirty-nine minutes after the fourth contact, as the result of which the May 18th curve is retarded in its steady descent and made to rise again. Whether this is to be associated with the eclipse can not be said at the present stage of the inquiry. Looking at the curve of residuals, the most striking features are the maximum at $18^h\ 05^m$, twenty-four minutes after the middle of totality, a minimum at $19^h\ 55^m$ thirty-nine minutes after fourth contact and a secondary maximum slightly larger than the first at $20^h\ 47.5^m$. The time interval from crest to crest is $2^h\ 42^m$, whereas the eclipse interval from first to last contact was $3^h\ 11^m$, and the total range of this wave was 1.0 minute of arc. Owing to the missing part of the curve before and about the time of the first contact, it is impossible to state with certainty whether anything abnormal occurred about that time. It would appear however, as though a minimum was reached about $16^h\ 47.5^m$, forty-one minutes after the first contact. The difference in time between this minimum and the next one at $19^h\ 55^m$, passing over the one at $17^h\ 45^m$, as this appears to be similar to the one of the previous day, is $3^h\ 07.5^m$, agreeing still more closely with the eclipse interval than the crest to crest period. For the wave from $16^h\ 45^m$ to $19^h\ 55^m$ the total range in declination is $0'.8$. Taking the average, we have as the period of the variation ($2^h\ 42^m$ and $3^h\ 07.5^m$) $2^h\ 56^m$ and for the average range (1.0 and 0.8), 0.9 minute of arc. While the indications are that this magnetic wave entered into the usual diurnal curve somewhat before the time of totality, its principal effect was felt after totality.

Confining our attention to about an hour before and after totality, we may say that in general the north end was deflected towards the west before totality and towards the east after totality—hence contrary to what occurred at Mauritius.

At *Sawah Loento*, declination changes were observed by Mr. G. L. Hosmer of the party from the Massachusetts Institute of Technology, Boston, this party being under the direction of Prof. A. E. Burton; their station was thirty-nine miles north of the central line of the shadow and forty-eight miles, about, northeast of van Bemmelen's station. In the figure (No. 2) are reproduced the declination changes observed on the day of the eclipse (the full curve), and on the day preceding (the broken curve).

Comparing the two curves, no striking departure between them is manifest with the exception of the peculiar drop from $16^h\ 10^m$ to $16^h\ 50^m$; this, while evident also in the May 17th curve, is more marked in that of the day following. This peculiar feature of the Sawah Loento curve does not appear in the one for Karang Sago, only forty-eight miles distant. It will be noted that after the occurrence of this feature there is as good an

Digitized by Google

agreement as could be expected between the curves at the two station considering the different methods and instruments used.

I have satisfied myself that the peculiarity in the Sawah Loento curv is not to be associated with the eclipse, nor to defective observing, but due to some purely local disturbance. Mr. Hosmer also made declin tion readings, at a slightly different station, on April 25, 27, and May 1901; the curves on these three days at first show a rapid decrease, the a rise followed by a drop, this drop corresponding to the one on Ma 18th.[1] The May 17th and 18th station was about one-half mile east the railroad tunnel through which passed a train going north, as M Hosmer has informed me, at about $11^h\ 20^m$ l. m. t. ($16^h\ 37^m$ May 17th Gr. m. astr. t.), this corresponding to the time of the deepest part of th drop. At about $11^h\ 40^m$ ($16^h\ 57^m$) a train passed to the south. The sta tion of April 25th, 27th, and May 5th was somewhat nearer the railroad and on account of fear of disturbing influence the change was made to th one of May 17th and 18th. The entire region abounds in coal mines.

The curve of residuals (+ + + +) or departures between the May 17th and 18th curves does not show with sufficient distinctness the minimum corresponding to the one at $16^h\ 47.5^m$ in the Karang Sago curve, doubtless on account of the local disturbing influence referred to above. The crest occurring about eighteen minutes after the middle of totality appears to be similar to the Karang Sago one which took place twenty-four minutes after the middle of totality. It will be seen that the curves of residuals are very similar after totality, the most interesting part of the Sawah Loento one being lost however, because of the cessation of the declination readings shortly after the fourth contact, the magnetic work having been only incidental to the work of the Massachusetts Institute party.

At each of the two most interesting stations we therefore lack, from one cause or another, a complete record of declination changes for the whole interval of observation (14^h–21^h).

At the *Batavia* Magnetic Observatory, 350 miles south of the central line, the middle of the eclipse occurred, according to van Bemmelen, at 18^h, May 17th, Gr. m. astr. t. ($1^h\ 07^m$ P. M. May 18th, l. m. t.). The full curve (Fig. 2) gives the declination changes on May 18th, whereas the dotted one, the mean changes for the interval May 9th to 17th and the curve shown by pluses (+ + + +), the residuals or departures between the two curves. The curve of residuals exhibits a series of waves having a period of about two hours, with a range varying from 0.3 to 0.5 minute of arc, the trough of one of these waves occurring at the time of middle of maximum obscuration, this trough meaning a deflection of the north end of the needle towards the west.

At the *Manila* Magnetic Observatory, approximately three times the

[1] See Mr. Hosmer's diagram in the Report of the Eclipse Expedition, *Technology Quarterly of the Massachusetts Institute*, March, 1902, p. 32.

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS.

Digitized by Google

Digitized by Google

distance north of the central line that Batavia was south of it, the maximum obscuration amounted to 0.52 (Sun's diameter being taken as unity), and took place at 2^h 38^m P. M., May 18th, 120th Meridian mean time or 18^h 38^m May 17th, Gr. m. astr. t. The full curve shows the declination changes on the day of the eclipse, whereas the dotted shows the mean changes for entire month, May, 1901, and the curve indicated by pluses (+ + + +), the residuals. The last exhibits a wave of about twice the length of the Batavia one, with its principal *crest* at 18^h 30^m, eight minutes before the middle of maximum obscuration. The average range of the wave is about 1.1 minute of arc. It may be of significance that as Manila and Batavia are in opposite magnetic hemispheres, so are the effects reversed which are exhibited near the times of maximum obscuration, a crest occurring in the curve of residuals in the first case, while there is a trough in the second one. Both places have east magnetic declination. It may also be significant that there is a distinct displacement in time of these two distinguishing features, the crest in the Manila residual curve occurring about the same amount of time later than the trough of the Batavia curve as the time of maximum obscuration at Manila is later than at Batavia.

An examination of the remainder of the curves in the figure (No. 2)—viz., *Zi-ka-wei*, in the northern magnetic hemisphere and *Melbourne* and *Christchurch* in the southern one—reveals the fact that no striking, general cosmical disturbance took place during the interval 14^h–21^h. A mere inspection shows that the principal effect observed at Karang Sago at 18^h 55^m and thereafter was not of the ordinary cosmical magnetic disturbance kind, it having no exact counterpart at the distant stations.

Horizontal Intensity Changes.

The horizontal intensity is the element which repeated experience has shown is the one peculiarly susceptible to magnetic fluctuations. It will therefore be especially interesting to examine the curves of changes obtained on the day of the eclipse. The plotted curves for the stations far beyond the region of visibility of the eclipse again confirm the fact, shown by the declination curves, that no general large magnetic disturbance affecting a large portion of the Earth took place during the interval, 14^h to 21^h.

Figure 4 gives the curves of changes for the two stations within the totality belt, Mauritius and Karang Sago, and for the two outside stations, Batavia and Manila.

Beginning with the bottom curve, *Mauritius*, we note a distinct depression in the curve for May 18th, the maximum depression being at 16^h, three minutes before the middle of totality, this depression being wholly lacking in the normal curve (the mean of the month). This decrease in horizontal intensity is well shown by the curve of residuals.

Digitized by Google

As in the case of the declination, the May 18th curve departs very markedly from the normal one for some time after the fourth contact. It is difficult to say just how much, if any, of the departures shown immediately before and after the fourth contact are attributable to the solar eclipse. If we assume that simply the depression near totality is due to the eclipse, then we may say that the maximum depression or decrease amounted to three units in the fifth decimal c. g. s. system, i. e., 3 gammas or $3/23820 = {}_{7}{}^{1}/_{40}$ part of H (about $1/3$ of the change observed at Rocky Mount, North Carolina, on May 28, 1900), or if we assume that the total change shown by the depression in the residual curve and the crest at $19^h\ 57^m.5$, viz., fifteen gammas, is due equally to two effects, one connected with the solar eclipse and the other due to some other cause, we should have about the same change as noted at Rocky Mount, viz., $7.5/23820\ H = {}_{31}{}^{1}/_{60}\ H$. However, I do not lay much stress upon such assumptions. *The fact of chief significance is that a noticeable decrease in horizontal intensity was observed at the Mauritius Magnetic Observatory at about the time of totality.* The director, Mr. T. F. Claxton, states furthermore that "on the originals [magnetograms] slight tremors are seen between $7^h\ 15^m$ and $7^h\ 50^m$, and occasionally between $8^h\ 05^m$ and 9^h A. M., Mauritius mean local time, the corresponding Greenwich mean astronomical times of May 17th being, respectively, $15^h\ 25^m$ to $16^h\ 00^m$ and $16^h\ 15^m$ to $17^h\ 10^m$."[1]

Passing next to *Karang Sago*, $2_h\ 52^m.1$ east of Mauritius, we again note a depression, clearly shown by the curve of residuals as having occurred at the time of totality. The residuals have been obtained (1) by a comparison of the May 18th and 17th curves (this curve is indicated by + + + +), and (2) by a comparison of the May 18th and mean for May 9th–17th curves (this curve is shown by × × × ×). It will be noticed that both curves show practically the same facts.

It should be noted that the May 18th curve had its rise to the morning maximum checked just before the first contact, and that the checking subsequently was of sufficient amount to produce a minimum at about the time when usually occurs a maximum. The period of the wave as shown by the residuals (+ + + +) from crest to crest with the minimum practically midway between, is $6^h\ 15^m$, or about twice that of the local eclipse interval or that of the declination wave.[2] Practically the same result is obtained from the second residual curve. The total range for the wave from the first residual curve is thirty-six gammas, and for the second, twenty-six gammas; assuming the mean to be nearer the truth, we have ${}_{56}{}^{3}/_{100}\ \mathrm{H} = {}_{11}{}^{1}/_{55}\ H$ or about $1/1200$.

Examining next the *Batavia* curve, we again note a marked depression about the time of maximum obscuration, the minimum occurring

[1] T. M., VI, p. 184.

[2] From the footnote p. 158 giving the circumstances of the eclipse, it will be seen that the whole eclipse interval is $5^h\ 08^m$.

Digitized by Google

at about $17^h\ 55^m$, or five minutes before middle of the eclipse. I have given on the diagram besides the normal curve resulting from the mean of the results, May 9–17, 1901, the mean for May of the entire series of Batavia observations 1882–1899, this curve being dotted. It is seen that the May 9th–17th one may safely be taken as a normal curve.

The wave shown by the residuals is not such a symmetrical one as at Karang Sago, possibly because of its great distance from the central line of shadow. The period from crest to crest is $4^h\ 50^m$ or nearly five hours, the first crest being not so sharply defined, however, as the second one. The range is nine gammas, or $9/36700\ H = 1/4078\ H$, considerably smaller than at Karang Sago.

At *Manila*, this observatory, as already pointed out, being in the opposite magnetic hemisphere to that of the three stations already examined, we find an increase near the time of maximum obscuration instead of the decrease, as obtained at each of the three stations examined. The maximum of the increase occurred at $18^h\ 35^m$, or three minutes before the time of maximum obscuration. Were we to reverse the curve of residuals and displace it about thirty-eight minutes to the left, we should behold a curve very similar to the Batavia one. The period from trough to trough is $4^h\ 15^m$, and that from crest to crest $4^h\ 0^m$, or average period about $4^h\ 08^m$. The range is about thirteen gammas or $\frac{13}{5815}\ H = \frac{13}{5815}\ H$. It is rather astonishing that both in declination and in horizontal intensity the observed ranges are greater at Manila than at Batavia, although the former station is three times as far from the central line as the latter.

It is again significant that the effects in the two hemispheres are the reverse of one another.

Vertical Intensity Changes.

Figure 5 gives all the curves obtained showing the changes in vertical intensity.

The curve of residuals for *Mauritius* appears to show nothing striking; the vertical force instrument may not have been sufficiently sensitive to record any small change that might have taken place about the time of totality, 1 mm. of ordinate being equal to 7.7 gammas. It is again evident that some pronounced effect continued for several hours after the fourth contact as already shown by both the declination and the horizontal curves; whether, however, this is to be ascribed to the eclipse can not, of course, be said.

At *Karang Sago*, no vertical intensity observations were obtained.

The *Batavia* curve shows clearly a depression at $18^h\ 20^m$—twenty minutes after the middle of the eclipse. Since the curves are plotted so that the intensity increases *downward*, the depression means an *increase* in the vertical intensity. The residual curve shows a distinct wave, the first crest occurring at $15^h\ 27^m.5$, the second one at 20^h, with a principal

Digitized by Google

depression at $18^h\ 20^m$, hence closer to the second crest, as in the case of the horizontal intensity. The period from crest to crest is $4^h\ 32^m$, or nearly the same as for the horizontal intensity which was $4^h\ 50^m$. The average range is thirteen gammas, or $\frac{1}{51400} Z = 1/1650$ of the absolute vertical intensity.

At *Manila* (see curve of residuals) we have a rise (decrease) culminating at $15^h\ 40^m$, next a depression (increase) at $17^h\ 37^m.5$ followed by a rise, in general, which reaches its summit at about $19^h\ 27^m.5$. The time interval from crest to crest is $3^h\ 47^m$—nearly the same as for the horizontal intensity which was $4^h\ 08^m$. The range is, on the average, six gammas, or $6/11060 = \frac{1}{1840}$ of the absolute vertical intensity, i. e., nearly the same ratio as for Batavia. Although the curve of residuals would apparently show an increase of one gamma at time of maximum obscuration, it will be seen that the principal and larger effect for about ½ to ¾ hour after totality was a decrease of the vertical intensity—again the reverse of the effect at Batavia.

VECTOR DIAGRAMS.

With the aid of the declination and horizontal intensity quantities given in Tables II and III, the values of X, the component directed positive towards the north, and of Y directed positive towards the east were computed.

The formulæ used were:

$$X = H \cos D;\ Y = H \sin D. \qquad (1)$$

If ΔD represents the observed declination, D, minus the assumed base line value, D_0, and ΔH represents similarly $H - H_0$, we have from (1) ΔD being expressed in minutes of arc:

$$\Delta X = \Delta H \cos D_0 - \sin D_0 \cdot \Delta D \cdot \frac{H_0}{3437.7}, \qquad (2)$$

$$\Delta Y = \Delta H \sin D_0 + \cos D_0 \cdot \Delta D \cdot \frac{H_0}{3437.7}, \qquad (3)$$

For *Mauritius*: $D_0 = 9° 27'$ W and $H_0 = 23820\gamma$, hence:

$$\Delta X = .986\,\Delta H - 1.14\,\Delta D,$$
$$\Delta Y = .164\,\Delta H + 6.84\,\Delta D.$$

For *Karang Sago* and *Batavia*: $D_0 = 1° 05'$ E and $H_0 = 36700\gamma$, hence:

$$\Delta X = 1.00\,\Delta H - .0189\,(H\Delta D),$$
$$\Delta Y = .0189\,\Delta H + 1.00\,(H\Delta D).$$

[The formulæ are expressed in terms of $H\Delta D$ in place of ΔD, as van Bemmelen did not publish the original quantities ΔD, but instead the $H\Delta D$ values.]

For *Manila*: $D_0 = 0° 50'$ E and $H_0 = 38100\gamma$, hence:

$$\Delta X = 1.00\,\Delta H - 0.161\,\Delta D,$$
$$\Delta Y = 0.0145\,\Delta H + 11.08\,\Delta D.$$

Digitized by Google

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY.

ASTOR ... DX AND
TILDEN FOUNDATIONS.

Digitized by Google

Figure 6. XY vector diagram for Mauritius. The curve for the day of the eclipse has been drawn from $0^h\ 10^m$ May 17th to $1^h\ 10^m$ May 18th, Greenwich mean astronomical time, or from 4 p. m. May 17th to 5 p. m. May 18th local mean time. For that portion of this interval for which we have but the hourly values, the curve is shown by broken lines. In order to fix in our minds the various events with reference to the local conditions, I shall use local mean time instead of Greenwich time, the conversion being always readily made by remembering that Mauritius is $3^h\ 50^m$ east of Greenwich and that the civil day begins twelve hours before the astronomical day.

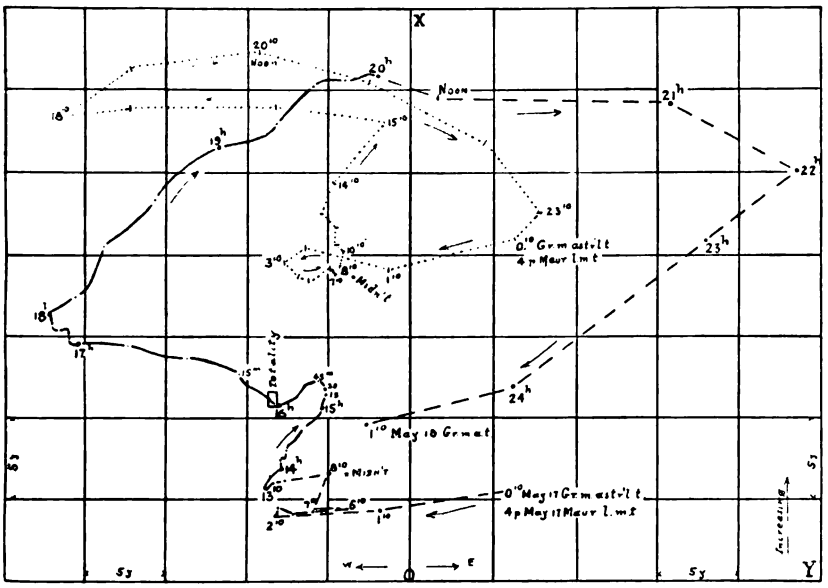


FIGURE 6. XY vector diagram for Mauritius.

We find that about one-half hour after the time of sunset ($5^h\ 31^m$ l. m. t.; $1^h\ 41^m$ G. T.) the curve is arrested in its westerly motion and begins to zigzag back and forth until about midnight, when it resumes its westerly motion only to be interrupted again shortly after 5 a. m. ($13^h\ 10^m$) the next morning (May 18th). It now continues northeastward until about 7 a. m., after which it performs a northwesterly motion, then a southwesterly one until a few minutes before totality, after which it pursues its regular daily course, reaching a maximum westerly point at $9^h\ 50^m$ a. (18^h), a most northerly one at about $11^h\ 45^m$ a. ($19^h\ 55^m$), and its most easterly position at $1^h\ 50^m$ p. (22^h).

Comparing this curve with the dotted one representing the mean curve described for the entire month of May, 1901, we find a small loop

Digitized by Google

described from about half hour after time of sunset to a little after midnight. We then have first a northwesterly motion, then a northeasterly one which is changed at 7^h a. (15^h 10^m) to a westerly one and the curve then continues in very much the same way as for the previous curve.

Aside from the fact that the area of the first curve is much larger than that of the mean curve, nothing worthy of special comment is shown in the May 18th curve with the exception, possibly, of the wavelet entering into the curve at *about* 6^h 50^m a. (15^h), or shortly thereafter. Sunrise occurred at 6^h 22^m, the first contact at 6^h 51^m, the middle of totality at 7^h 53^m (16^h 03^m), and the fourth contact at 9^h 05^m (17^h $14^m.5$). In the mean curve we unfortunately lack closer observations than the hourly ones, so that it is impossible to make a strict comparison of the two curves at this interesting juncture. This much we may say, that if there was an eclipse effect, it occurred in the form of a wave, and did not consist of any sharp, sudden changes, and that the total changes in the components may have been about 2 to 4 γ. The most noticeable fact is the drop near totality, as already pointed out when considering the horizontal intensity curves.

Figure 7. Karang Sago XY vector diagram. Here we notice in the curve for May 18th a small loop described at the time of totality and very soon thereafter a larger one. The small loop is similar to the one described in the curve obtained during the total solar eclipse of May 28, 1900, at Rocky Mount, North Carolina. Both of these loops are absent in the May 17th curve, drawn with the aid of fifteen minute values. There is a loop described in the May 17th curve from 10^h 42^m a. (16^h) to 12^h 57^m p. (18^h 15^m), which judging from van Bemmelen's vector diagram for the mean interval, May 9th–17th, is what normally occurs at about this time. Unfortunately, owing to the failure of the work on May 18th before 16^h, we can not say whether this normal loop had or had not a counterpart on that day. The greatly altered character of the curve from 16^h to 18^h, as compared with that of the day before, is to be noted.

Figure 8. XY vector diagram for Batavia. Comparing the May 18th curve and the dotted one for the mean interval May 9th–17th, nothing requiring special remark occurs until the deflection of the curve towards the west at about totality followed by a much larger deflection towards the east at 19^h and afterwards. This is significant for our inquiry: the extreme westerly position of the Karang Sago curve occurs about eighteen minutes earlier than at Batavia, i. e., about the same difference of time as between the times of the middle of the eclipse at the two places; the same fact is true for the larger effect, viz., for the most easterly position of the curves.

Figure 9 gives the mean May XY vector diagram for Batavia for the entire period, 1883–99.

Figure 10. ZY vector diagram for Batavia. On account of the dis-

Digitized by Google

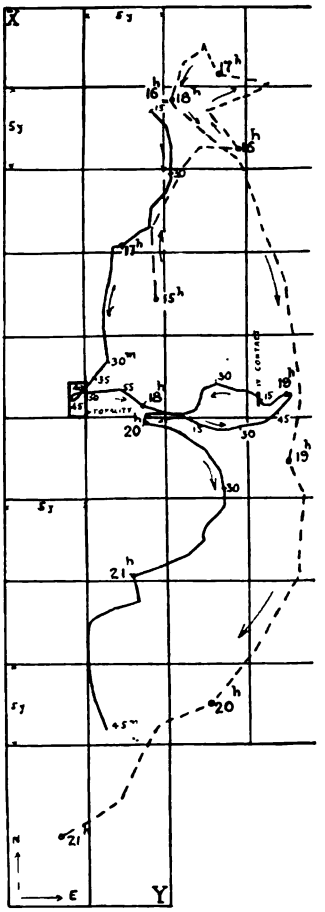


FIGURE 7. XY vector diagram for Karang Sago.

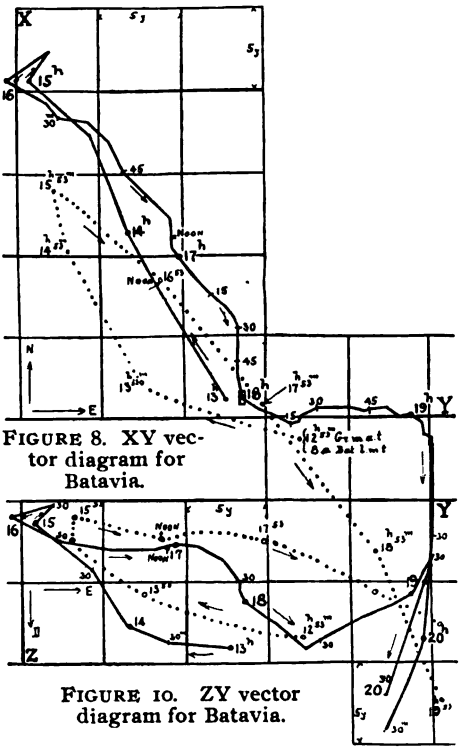


FIGURE 8. XY vector diagram for Batavia.

FIGURE 10. ZY vector diagram for Batavia.

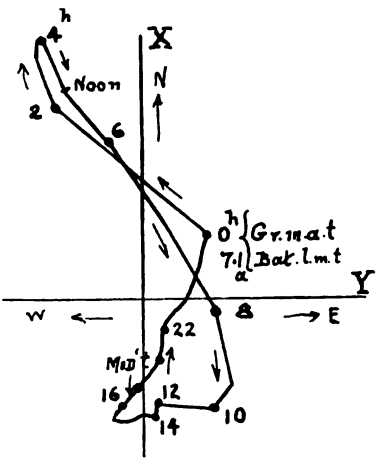


FIGURE 9. The mean May XY vector diagram for the entire period, 1883–99.

Digitized by Google

turbances from electric car lines, van Bemmelen chose as his normal vertical intensity curve, the mean one for May, 1887. This is practically the same as the mean May curve for the interval, 1883–99.

Of special note here is the more rapid descent of the curve of May 18th (than for the normal one) beginning about one-half hour before middle of eclipse and leading to a noticeable depression at about the same time thereafter; next, a rise takes place, the highest point being reached at about $19^h\ 30^m$ and then once more a descent occurs.

Figure 11. XY vector diagram for Manila. The three stations thus far considered were in the southern magnetic hemisphere. We next pass to Manila, in the northern magnetic hemisphere. The vector diagram now proceeds contrary to the direction of the hands of a watch. The curve for the day of the eclipse begins at 20^h May 16th, and goes to May 17th, 21^h, Greenwich mean astronomical time, or from May 17th, $4^h\ 04^m$ p to May 18th $5^h\ 04^m$, local mean time. Sunset on May 17th occurred at $5^h\ 41^m$ ($21^h\ 37^m$ G. T.). As at Mauritius, the curve at about this time is retarded and performs a number of backward and forward motions during the night. For the mean May curve (dotted one), these motions form a loop which opens up about an hour after midnight. The sun rose on May 18th at $6^h\ 13^m$ ($10^h\ 09^m$ G. T.). The curve continues now steadily until its most easterly position is reached, and next proceeds to its most northerly position. Some time after noon a more rapid motion to the southeast takes place than shown by the mean curve, culminating in a small loop just a little before the time of maximum obscuration; after the formation of this loop a descent occurs to the southwest in place of to the southeast. There is thus a noticeable difference in the two curves at about the time of maximum obscuration of the Sun.

It will be noticed that the loop described a little before the time of maximum obscuration is very similar to the one of the mean curve formed after sunset and continuing until a little after midnight; the areas of the two loops compare as about 1 : 12. The small loop May 18th is described for Manila in a direction contrary to that of the hands of a watch, whereas at Karang Sago it proceeds clockwise. It is furthermore of interest to note that the loop described before midnight at Manila (mean curve), goes in the clockwise direction, whereas that for Mauritius (mean curve) goes anti-clockwise.

The enlarged vector area on May 18th over that for the mean curve is again noticeable, as at Mauritius.

Before summing up the facts thus far found and attempting to correlate them, it will be advantageous to consider some previous observations made during the time of total solar eclipses for stations near the central line of shadow.

Digitized by Google

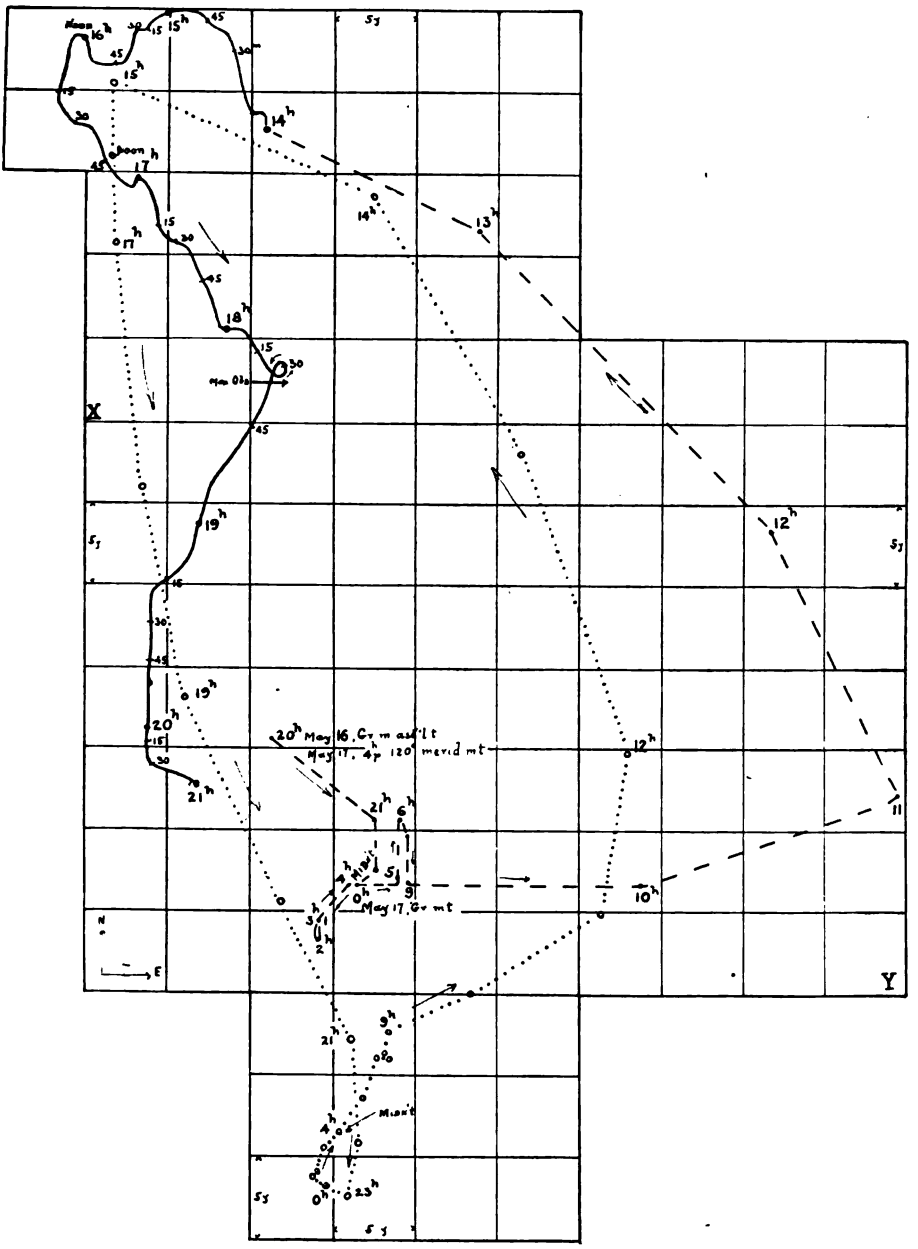


FIGURE 11. XY vector diagram for Manila.

Digitized by Google

Digitized by Google

Figure 12. Results of Batavia and Buitenzorg eclipse, December 12, 1871. In this figure we have plotted the two curves of residuals or of deviations from the normal values. It is seen that they are very similar, as their close proximity, of course, demands. Any effect that may have been observed will therefore be verified by the similar result obtained at a neighboring station by an independent observer. In order to see precisely how the residual waves, shown in the two upper curves of the figure, entered into the declination curve actually observed, I have plotted the normal curve as obtained from Bergsma's publication and with its aid and that of the residual curves, the original curve for December 12, 1871 obtained at Batavia, has been reproduced. Since the declination was east and Batavia is in the southern magnetic hemisphere, we have a minimum east declination normally near 8 A. M., after which the declination steadily increases, reaching a maximum about 2 P. M. On the day of the eclipse, however, it will be seen (3d curve of figure, counting from top) that at about the time of the first contact, the steady rise is retarded, and the easterly declination begins to decrease instead of increasing. At about $9^h\,45^m$, it begins to go up again, continuing so until about the time of totality, after which another descent occurs for about one-half hour, when the usual ascent is once more resumed.

Now at the station Rocky Mount, North Carolina, since the declination was west, we have normally a similar state of affairs with regard to west declination, viz.: a rise from a morning minimum to an afternoon maximum, as pertained to the normal march of the east declination at Batavia. As the total eclipse of May 28, 1900, occurred, however, about 1¾ hours earlier in the day, I have plotted the Rocky Mount declination curve (the bottom one) so that the time of middle of the 1900 eclipse would fall under that for Batavia in 1871, and that increasing ordinates would mean increasing west declination. The surprising similarity of the effects which entered into the normal declination curves at the two stations is at once apparent.

At *Rocky Mount on May 28, 1900*, we had before totality an increase of west declination, i. e., a deflection of the north end of the needle towards the *west*, and after totality, a diminution of west declination, or a deflection towards the east.

At *Batavia on December 12, 1871*, easterly declination was increased before totality, hence there was a deflection of the north end of the needle towards the *east*, and after totality, a diminution of easterly declination, or a deflection of the north end towards the west. Or if we refer the deflections to the south end of the needle, since Batavia is in the southern magnetic hemisphere, the same fact took place with regard to the south end (a deflection to the west before totality followed by one to east after totality), as at Rocky Mount with regard to the north end.

The total range of the deflection from west to east at Rocky Mount

Digitized by Google

was about 0′.9, and as the diurnal range was about 10′.8, the range of the eclipse magnetic variation was about $\frac{1}{12}$ of that of the total solar diurnal variation. At Batavia, in 1871, the range of the magnetic variation about the time of the eclipse was about 0′.82 and at Buitenzorg 0′.66, the mean being 0′.7, which is about $\frac{1}{8}$ of the normal diurnal range at Batavia at that time.

The two curves of residuals, Batavia and Buitenzorg, each reveal one large wave of a period about 4½ to 5 hours, having a range of about 1½ or 1¾ minute of arc and a smaller one nearly symmetrically situated with reference to the time of totality, with a period of about ¾ hour, and having the range as already given. The total time of the eclipse was $2^h\ 59^m$.[1]

MAGNETIC OBSERVATIONS MADE IN ITALY DURING THE TOTAL SOLAR ECLIPSE, DECEMBER 22, 1870.

Under the direction of Diamilla-Müller, declination readings[2] were taken at Terranova (Sicily), in the belt of totality, Naples, Rome, Livorno, Florence, Bologna, and Moncalieri, the obscuration, beginning with Naples, being as follows: 0.949, .928, .900, .899, .891, and .877. Some observations were also made at Genoa.

At Terranova, where Diamilla-Müller observed, the beginning of the eclipse occurred at $12^h\ 41^m$ p., middle of totality, at $1^h\ 57^m$ p., and the end at $3^h\ 18^m$, local mean time. Bergsma[3] when reviewing this work, found that a scale value twice too large had been used at Terranova. In the table below are given the results at this station, using the proper scale value. Beginning at $12^h\ 40^m$ and continuing until $2^h\ 40^m$, the readings were taken nearly every minute; in the table the quantities given for this interval are, therefore, the means of several readings.

[1] Bergsma concluded that his observations at Batavia and Buitenzorg did not show any magnetic effect to be associated with the total solar eclipse. He apparently, in common with others, was looking for larger effects and possibly for such as would be similar to well-defined, sudden perturbations.

[2] Reports on this work will be found in *Comptes Rendus*, LXXIII, pp. 575 and 1230. The observations are given in detail in: *Eclisse totale del sole del 22 Dec.* 1870. *Osservazioni meteoriche e magnetiche eseguite in Terranova di Sicilia. Relazio di* D. E. DIAMILLA-MÜLLER e Lucciano Serra.

[3] See Bergsma's paper already cited. In Bergsma's paper will be found the results at all of the stations. Van Bemmelen, in his paper, gives an extract from the Terranova observations, after correcting the same for erroneous scale value.

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS

Digitized by Google

Digitized by Google

TABLE VI. Results of declination readings at Terranova (Sicily) during the total solar eclipse of December 22, 1870.

[$D=D_e+\Delta D$, D_e being the least west declination on December 22d, viz.: at $9^h\ 30^m$.]

L. M. T.	ΔD	L. M. T.	ΔD	L. M. T.	ΔD	L. M. T.	ΔD	L. M. T.	ΔD	L. M. T.	ΔD
h m	′	h m	′	h m	′	h m	′	h m	′	h m	′
8 0a	1.28	10 0	0.33	12 0	4.37	1 0p	4.37	2 0	3.23	3 0	4.92
10	0.78	10	1.00	10	4.37	5	4.22	5	4.37	5	
20	0.44	20	2.23	20	5.03	10	4.21	10	4.56	10	5.25
30	1.00	30	2.23	30	4.92	15	4.33	15	5.21	15	
40	0.44	40	2.68	40	5.48	20	3.95	20	5.41	20	5.48
50	0.56	50	3.24	45	6.80	25	3.80	25	5.64	25	6.03
9 0	0.56	11 0	3.24	50	6.66	30	3.80	30	5.80	30	5.25
10	0.44	10	3.68	55	5.10	35	3.66	35	5.26	35	5.48
20	0.11	20	4.13			40	3.31	40	4.64	40	4.92
30	0.00	30	3.80			45	3.36	45		50	4.92
40	0.44	40	4.25			50	3.62	50	4.25	4 0	4.92
50	0.78	50	5.25			55	3.16	55	4.25	10	4.92
10 0	0.33	12 0	4.37			2 0	3.23	3 0	4.92	5 0	5 92

Plotting these results, as also those at the other seven stations named, it would seem as though this day was not a magnetically calm one. We have, however, at all of the stations the opposite kind of an effect associated with the eclipse to that already explained for the United States eclipse stations, the magnitude of the effect, owing to some cause, being, moreover, two to three times that hitherto observed. Thus at Terranova, for example, the beginning of the eclipse ($12^h\ 41^m$) marked in the table by a horizontal line, occurred about the time when the needle ordinarily is reaching its afternoon elongation, which, since D is west, means its maximum westerly declination. Soon after first contact, the declination begins to diminish very rapidly, reaching a minimum at $1^h\ 55^m$—just before middle of totality. It then begins to increase again, reaching a maximum value at about $2^h\ 30^m$, or about half an hour after totality, after which it again drops to minimum at $2^h\ 52$, etc. In other words, immediately *before* totality, the north end of the declination needle was deflected towards the east and afterwards it was deflected to the west for about half an hour. This would correspond to the effect of a north end repelling pole moving in the wake of the eclipse shadow. Supposing the range of the eclipse effect to be the difference between the minimum immediately before totality and the first maximum thereafter, we obtain 2′.6.

Digitized by Google

As stated, the same facts as at Terranova are shown at the other seven stations and there is again clearly exhibited a displacement of phase in direct relationship to the time of maximum obscuration.

It would seem as though in this series of stations we have to deal with a combination of effects due possibly to various causes.

It should be recalled that the United States eclipse of May 28, 1900, occurred in the morning, whereas the Italian one of 1870 took place in the afternoon. Turning back to the discussion of the Manila declination observations of May 18, 1901, the eclipse occurring in the afternoon, Manila being in the northern hemisphere and having east declination, it will be seen that the declination was increased just before maximum obscuration, i. e., the needle was deflected to the east before maximum obscuration just as at Terranova.

This constitutes all of the magnetic observations made during total eclipses that are readily available for the present inquiry. Usually the observations made previously refer either to partial eclipses or to stations at great distances beyond the belt of totality—in several instances beyond the zone of visibility of eclipse.

SUMMARY OF THE PRINCIPAL MAGNETIC FACTS THUS FAR OBTAINED DURING TOTAL SOLAR ECLIPSES.

In Table VII a tabular summary has been attempted of the principal facts thus far obtained. The first two columns give, respectively, the date of eclipse and name of station, the third the magnetic hemisphere in which the station is located, the fourth, the local mean time of maximum obscuration, the fifth, whether the declination of the north end is east or west, the sixth and seventh columns state, respectively, in which direction the north end of the needle was deflected, on the average for half an hour before and after totality, the eighth and ninth, respectively, whether the horizontal intensity was increased or decreased, on the average for half an hour before and after totality, the next, whether the vertical intensity was increased or decreased at about the time of totality, the next, which end of the needle was attracted, as shown chiefly by the deflection in declination.

I have arranged the entries so that the eclipses which occurred about the same time of day come together. Group I exhibits the results at five stations for three eclipses which all occurred in the afternoon, two stations being in the northern magnetic hemisphere and three in the opposite one. We see at once that the effects are reversed in the two magnetic hemispheres.

Digitized by Google

TABLE VII. Tabular Summary of the Principal Magnetic Facts thus far obtained during Total Solar Eclipses.

Group	Date of Eclipse.	Station.	Magnetic Hem.	L.M.T. of Max. Obs.	Declination N. end.	Defl'n N. end of needle Before Totality	Defl'n N. end of needle After Totality	Hor. Int. Before Totality.	Hor. Int. After Totality.	Vert. Int. at Totality.	End of needle attracted.
				h m							
I	1870, Dec. 22	Terranova, Sicily	N	1 57 p	W	E	W	—	—	—	S
	1901, May 18	Manila, Philippines	N	2 38 p	E	E	W	Incr.	Decr.	Decr.	S
	1901, May 18	Batavia, Java[1]	S	1 07 p	E	W	E	Decr.	Incr.	Incr.	N
	1901, May 18	Karang Sago, Java[1]	S	0 25 p	E	W	E	Decr.	Decr.	—	N
	1901, May 18	Sawah Loento, Java	S	0 23 p	E	—	E	—	—	—	N
II	1900, May 28	Union Springs, Ala.	N	7 53 a	E	W	E	—	—	—	N
	1900, May 28	Rocky Mount, N. C.	N	8 40 a	W	W	E	Decr.	Incr.	—	N
	1900, May 28	Toronto, Canada	N	9 0 a	W	W	E	Decr.	Incr.	Decr.	N
	1901, May 18	Mauritius,	S	7 53 a	W	E	W	[Dec.	atTot	?	S
	1871, Dec. 12	Batavia, Java	S	10 28 a	E	E	W	—	—	—	S

Similarly Group II, which contains, for three morning eclipses, the results at five stations, three in the northern hemisphere and two in the southern one, again shows, in general, a reversal of effects in passing from one magnetic hemisphere to the other.

Comparing the results in the two groups for the stations in the same hemisphere, it is seen that there is, likewise, a reversal of effect according as the eclipse occurred in the morning or in the afternoon.

Hence, the precise effect of the eclipse magnetic variation is: (1) opposite in the two magnetic hemispheres, (2) opposite for the morning and afternoon hours.

In other words, *the nature of the eclipse variation is analogous to that of the diurnal variation, differing from it only in degree.* For, if we examine the map of the Schuster-von Bezold equipotential lines of the magnetic field, which, by its sliding around the Earth from east to west[2] causes the diurnal variation, it is found that the diurnal variation in the northern magnetic hemisphere can be regarded as produced by a north end attracting pole situated in the upper atmospheric region and moving in the direction of the apparent motion of the Sun; about nine hours thereafter, the north end attracting pole gives way to a south end attracting one moving in the same direction as before, so that for any one station opposite effects are produced in the diurnal variation according to the time of day. In the southern magnetic hemisphere the mag-

[1] Dr. van Bemmelen in his Report likewise reached the conclusion that the effects at Batavia and Karang Sago were those due to a north end attracting pole.

[2] See *T. M.* Vol. IV, p. 48, or Vol. III, p. 111.

Digitized by Google

netic system is the reverse of the one described, a south end attracting pole preceding the north end attracting one, thus producing reversed effects in passing from the one hemisphere to the other.

THE BEARING UPON OTHER MAGNETIC VARIATIONS.

I believe that we may now accept it as a fact that a slight magnetic variation occurs during the time of a total solar eclipse. Its origin must, apparently, be ascribed to some change produced in the electrification of the upper regions of the atmosphere when the Sun's rays are cut off by the interposition of the Moon. Since, as already stated in the preface, we do not get similar effects by cutting off the sun light which reaches the surface of the Earth, it would seem as though there are associated with sunlight certain radiations which are eliminated or deflected by some process taking place in the upper atmospheric regions, and which, in consequence, fail to reach the Earth's surface.

The recent results of several investigators would seem to make it probable that owing to the pressure of light now known to exist, thanks to the experiments of Lebedew, Nichols, and Hull, there are continually being brought towards the Earth, radiations of some kind affecting the magnetic needle, for example, cathode rays, which, when they get within the reach of the lines of the Earth's magnetic force are, according to the theory of Arrhenius and Birkeland, deflected and made to travel in circuitous paths, and for this reason, are very largely, if not entirely, prevented from actually reaching the Earth's surface. Owing to the greater inclination of the lines of force near the magnetic poles, it is believed by these authors that there the cathode rays penetrate farther into the atmosphere and produce the polar lights.

But if the Moon can produce a magnetic effect by gradually cutting off or deflecting the solar radiations affecting magnetic needles, and then gradually supplying these radiations again, why does not the Earth produce a similar effect every day? One side of the Earth is daily eclipsed. Manifestly we should get a much larger effect.

Let us suppose that the magnitude of the effect produced on any one magnetic element, as for example, the range of the declination variation, be directly proportional to the amount of sunlight a body is able to cut off from our atmosphere. Since the Earth and Moon are practically at the same distance from the Sun, we may say that the amount of sunlight these bodies cut off will approximately be to each other as the squares of of their diameters, i. e., as $(3.67)^2 : 1$ or as $13.5 : 1$.

At Rocky Mount the diurnal range on May 28, 1900, was 10′.8 and the eclipse magnetic variation should, therefore, according to the hypothesis, be about $10.8/13.5 = 0'.8$; the quantity actually obtained was 0′.9. At Mauritius on May 28, 1901, the diurnal range was 6′.6; hence, the computed eclipse magnetic variation would be $6.6/13.5 = 0'.5$; the range of the wave near totality was found to be 0′.65.

Digitized by Google

Not having all of the hourly values for Karang Sago so as to admit of the determination of the diurnal range, a calculation of the expected solar eclipse variation range must be omitted; from the hourly values, from 8 A. M. to 6 P. M., it would appear, however, that the computed range might be about 0′.2 to 0′.4. The range of the small wave which has its trough at totality and crest about 18 minutes afterwards is 0′.5. If this be the true eclipse magnetic effect, then the longer wave occurring at Karang Sago considerably after totality must be ascribed to other sources. At Batavia on December 12, 1871, the diurnal range was 6′.0, the computed eclipse range, therefore, 6.0/13.5=0′.44; the mean range observed at the two neighboring places, Batavia and Buitenzorg, was 0′.7. At Terranova, December 12, 1870, the diurnal range was about 6′.8, the computed, 0′.5 and the observed range 2′.6; it has, however, already been pointed out that there was apparently a combination of effects at this station. We see that, in general, the observed ranges of the solar eclipse magnetic variation are of the order required by the hypothesis. Tabulating the quantities of which we feel most certain, we have:

Station.	Eclipse.	Declination		
		Solar diurnal range.	Solar eclipse range	
			Computed.	Observed.
Rocky Mount	May 28, 1900	10′.8	0′.8	0′.9
Mauritius	May 18, 1901	6 .6	0 .5	0 .6
Batavia	Dec. 12, 1871	6 .0	0 .4	0 .7

While the agreement is, in general, good, the calculated quantities appear a trifle too small; should we base the calculation on the observed summer diurnal ranges, then, a still better agreement would be obtained.

Let us next examine the seasonal change in the diurnal range of the magnetic declination and, as the principal part of the diurnal variation occurs during the day hours, let us see whether this seasonal change is in any way related to the varying diurnal intensity of solar radiation received during the course of the year. In Appendix 71 of the Annual Report of the Chief Signal Officer, U. S. A., for 1885, Prof. William Ferrel discussed this variation in its bearings on changes of temperature, and deduced formulæ and tables by means of which the relative diurnal

Digitized by Google

intensity of solar radiation may be computed for any latitude and time of year. With the aid of his tables the quantities in the last column of the following table have been derived; it will be seen that the agreement between the observed and computed quantities is quite satisfactory except for Potsdam. Very nearly the same results are obtained if it is assumed that the solar radiation received at any place on the earth is proportional to the square of the time between sunrise and sunset.

Station and Year.	Latitude.	Ratio of the mean diurnal range of the magnetic declination in the summer months to the mean of the winter months.	
		Observed.	Calculated.
Baldwin, Kansas, 1901	38°.8 N	1′.79	1′.78
Los Angeles, California, 1882–'89	34 N	1 .56	1 .60
San Antonio, Texas, 1890–'95	29 .5 N	1 .53	1 .47
Potsdam, Germany, 1893	52 .4 N	1 .86	2 .72
" " 1898	"	2 .20	2 .72
Mauritius,	20 .1 S	1 .35	1 .35

The amount of solar radiation received or cut off from the atmosphere in the course of the Earth's rotation varies, furthermore, during the year because of varying distance of the Earth from the Sun. The variation of the radius vector amounts to about $\frac{1}{30}$ of its mean distance, and, as the intensity varies inversely as the square of the radius vector, its variation will amount to about $\frac{1}{15}$ of its average value. Thus, for example, the diurnal range at Potsdam was, on the average for the year 1898, about 7′; the calculated range of the small annual variation would therefore be about $7/15 = 0'.47$ and as Dr. Lüdeling in his discussion of the Potsdam observations found the range for this year to be 0′.53, we again have as satisfactory an agreement as could be expected.

It is patent that the results thus far obtained, besides having a bearing on the general theory of the Earth's magnetism, have a special application to some of the variations ascribed to the Moon, since the amount of solar radiation reflected to the Earth by the Moon would vary in accordance with its varying position with reference to the Sun and the Earth.

As the chief results of this paper, I desire to have considered: the establishment of the facts that an observable magnetic variation makes itself felt during the time of a total solar eclipse, and that this variation is analogous in its nature to the solar-diurnal variation, differing from it only in degree.

Digitized by Google

RECORDS OF EARTHQUAKES ON QUICKLY-DRIVEN MAGNETOGRAPHS.

By C. Coleridge Farr, D. Sc.

On the morning of Saturday, November 16, 1901, Christchurch, New Zealand, was visited by a severe shock of earthquake. The earthquake did much damage in the Cheviot District about sixty miles to the northeast from here, wrecking chimneys, etc., over a considerable area. In this city the chief and almost only damage done was to the spire of the cathedral which was cracked in two places, and the portion of the lower crack has since had to be removed. The earthquake was among the more severe of New Zealand shocks.

The magnetographs at the Christchurch Observatory, though in adjustment, were not recording at the time; indeed we proposed to commence our record on the following Monday morning. They are of the Kew type, and, in view of the proposal of the "International Magnetic Cooperation," arrangements had been locally made for driving the drums, when desired, at a peripheral speed of 31 millimeters in 8 minutes.

On visiting the magnetograph shortly after the first shock, the vertical-force instrument was found to have been thrown out of adjustment, while the others remained unharmed. It very soon appeared that the disturbances were not over with the first shock, and it was therefore decided to attempt to record some of them by running the magnetographs at the high speed. This high-speed running was continued from about noon on Saturday till 7.30 P. M. on Sunday, when our supply of quick paper ran out. It was started again at 11 A. M. on Monday, and continued till 6 P. M. on Wednesday. This process, besides very thoroughly testing the arrangements for high-speed running, gave also the following information. For cordial assistance in keeping the instruments going at the high speed, I am indebted to my assistant, Mr. N. F. Skey, B. Sc.

We thus recorded four shocks, all of them perceptible to some of the residents of the Cheviot District, but none of them felt by either Mr. Skey or myself in Christchurch. There are also on the sheets many small, sudden irregularities which can scarcely be ascribed to ordinary magnetic phenomena.

The records of the declination instrument are all of the same geneeral character, namely, a very slow wave motion symmetrical to the original undisturbed position, which gradually became damped out. I have measured up the three original records which are clearest, and

Digitized by Google

they all gave practically the same period, viz., 137 seconds for a complete wave. The damping coefficient k in an expresion of the form

$$Y = Ae^{-kt} \cos \frac{2\pi t}{T}$$

is very nearly the same for all, and approximates closely to .008. For ordinary oscillation round a vertical axis the magnet's complete period is 10.34 seconds, and the damping coefficient .019, while as a pendulum the complete period round a horizontal axis for small vibrations would be 1.11 seconds. It seems thus impossible to account for these long waves as a combination of these very small shorter vibrations.

The records from the horizontal force (bifilar) magnetograph are on the whole much clearer, and in two cases in the originals it is possible to see the whole sequence of events. In all four cases, the complete period is much the same, viz.:

$A = 41.7$ seconds.
$B = 41.8$ "
$C = 41.3$ "
$D = 41.3$ " ,

the differences being thus not more than might be expected to arise from the difficulty of deciding on the exact crest of a wave. The character of the motion is evidently not a simple sine curve with a damping factor, for in all cases but A the force has apparently suddenly increased at the time of the shock and has fallen to its original value very gradually, superposed upon this gradual fall being the wave already referred to. The coefficient "k" as a factor of decay of the form e^{-kt} taken with regard to the instantaneous position of rest is for the record

A not attainable
$B = .0026$
$C = .0019$
$D = .0015$

or very much the same for all.

In contrast with these periods and damping constants are those associated with the ordinary oscillation round a vertical axis where the period is 13.07 seconds, and $k = .0213$. This may be seen, too, in the the bifilar record of a disturbance which took place during the high-speed running. If this is an earthquake, it is of quite a different character from the rest, and the magnet has simply performed ordinary oscillations and come naturally to rest. The declination record corresponding to this is too indistinct for reproduction, but it also shows ordinary oscillation. For pendulous swings, the bifilar periods are about one second.

Thus in these records we have waves both in declination and horizontal force, in the one case 13 times and in the other 3 times, as long as the longest natural period of the magnets and whose damping constants "k" are in the first case 2⅓ times smaller and in the other 10 times

Digitized by Google

smaller than those connected with the longest natural periods. That these waves are due to slow changes of level seems improbable, for then, apart from the difficulties of explaining the records in this way, the Milne seismograph in Wellington (the one since erected here was not then in operation) would have recorded them, since Wellington is not more distant from the seat of the disturbance than Christchurch. The tape, on the contrary, shows a series of comparatively small tremors during nearly the whole period the magnetographs were being driven at the high speed, and corresponding to one of the largest magnetograph records, *C*, is a particularly small tremor. Many of the tremors much larger on the seismograph tape were not recorded at all on the magnetographs. It thus seems that we have here a real magnetic effect.

The district in which the shocks were most severely felt has been to some extent examined by me magnetically, and appears to be magnetically uniform. A very large disturbance, however, exists to the north, apparently culminating near Nelson, about 70 miles north from Cheviot. This disturbance extends over the whole northern portion of the Middle Island. I am unable at present to say how far south of Nelson its influence may be detected.

Since these records were obtained an earthquake has been reported to have been felt at New Plymouth, at the foot of Mt. Egmont, on the southwest of the North Island of New Zealand, and another at Kamgiora, about 20 miles north of Christchurch, during times when the magnetographs were being driven at the high speed. In neither of these cases did the magnetographs record anything abnormal, but on January 9, 1902, from 11.02 A. M. to 11.40 A. M., during slow-speed driving, there was a most marked disturbance of the curves, which has none of the appearances of an ordinary magnetic disturbance. An earthquake was on that day recorded on the Milne seismograph, commencing at 11.29 A. M. and ending at 0.17 P. M. Thus in this case the magnetic effect preceded the seismic effect by 27 minutes, and ended 37 minutes before it. The striations in the declination record are due to the light, and exist on the base line also.

Digitized by Google

MAGNETIC OBSERVATIONS ON LAND BY THE AUSTRIAN NAVY BETWEEN 1896 AND 1901.[1]

[Abstract.]

A pamphlet recently issued by the Hydrographic Office of the Austrian Navy gives an account of a creditable series of magnetic observations made as part of the scientific work carried out on shore during the cruises of His Majesty's ships *Albatros*, *Freundsberg*, *Saida*, and *Donau*, between the years 1896 and 1901. Each of these ships was supplied with a complete magnetic outfit, including magnetometer, astronomical theodolite, dip circle, tent, chronometer, etc., and the work placed in charge of a special officer. In each case the field instruments were carefully compared, generally both before and after the cruise, with the standard magnetic instruments in the observatory of the Hydrographic Office at Pola, and the results corrected accordingly. In transporting the instruments the greatest care was used to prevent their receiving injury of any kind. The results of the observations, referred to the Pola Magnetic Observatory standards, are given below.

It is questionable, of course, whether the dip corrections as obtained at Pola could be properly applied for dips differing so greatly from that at Pola.

At Tokyo, comparisons were made on August 9–11, 1898, between the observatory instruments and those of the *Freundsberg*. With the aid of the comparisons of the latter instruments made at Pola in April, 1898, and July, 1899, the following figures result:

	West Decl.	Hor. Int.
Schneider (Pola)—Tanakadate No. 3 (Tokyo)	+ 1′.4	28γ

[From a smaller number of comparisons Lieutenant Karl Kailer, Austrian Navy, had found in November, 1895, + 2′.7 and + 16γ respectively.]

	Inclination.
Wild (Pola)—Casella No. 5615, Needle 1 (Tokyo)	— 4′.2

DESCRIPTIONS OF STATIONS.

1. *Colombo.* In the garden of the Austrian-Hungarian consul, Mr. Whist-Bungaloev, at same place where a few months later Lieutenant Karl Kailer, Austrian Navy, of the *Aurora*, observed. The dip circle was mounted about sixty steps south of the magnetometer. Meadow with rocky bottom.

2. *Singapore.* In the open place in front of the Raffles Girls' and Boys' School. Alluvial soil covered with grass sod. Dip circle was mounted sixty steps from magnetometer.

3. *Albatros Cove (St. George Island-Isabel).* On account of the extremely abundant tropical vegetation it was necessary to clear out a place about six hundred meters from the ship's anchorage. Dip circle mounted seventy steps southwest of magnetometer. Surface consists of volcanic rocks overlaid with thick humus layer.

4. *Marau Sound.* Densely wooded point of the Island Crawford owned by the Norwegian traders Svenson and Nerdrum. Dip circle fifty steps from

[1] Fortlaufende Nr. 13. Veröffentlichungen des Hydrographischen Amtes der K. u. K. Kriegs-Marine in Pola. Gruppe IV. *Erdmagnetische Reise-Beobachtungen.* III. Heft. Herausgegeben von der Abtheilung "Geophysik." Pola, 1902. 52 pp, 25 x 32 cm.

Digitized by Google

TABLE OF RESULTS.

[Uncorrected for diurnal variations.]

No.	Place	Lati-tude	Long. E. of G.	Date	Declination		Hor'l Intens. (C. G. S.)	Inclination.	
					Local Mean Time	Result			
		° ′	° ′		h m	° ′	γ	° ′	
1	Colombo	6 58.1 N	79 52.2	1896, Jan. 11	.....	.....	37988	8 21.4 S	Voyage of the *Albatros* to Asia and the South Seas; Lieut. N. M. von Vitturi, Austrian Navy.
2	Singapore	1 17.8 N	103 53.2	1896, Feb. 6, 7	1 58 p	1 41.0E	38377	15 14.9 S	
3	Albatros Cove	8 27.5 S	159 32.0	1896, June 11-13	3 50 p	8 44.0E	37131	26 05.4 S	
4	Marau Sound	9 49.1 S	160 48.5	1896 July 28, 29	10 39 a	8 34.9E	36857	27 51.5 S	
5	Cooktown	15 27.6 S	145 15.2	1896, Sep. 16, 17	2 35 p	5 31.9E	36367	40 32.3 S	
6	Sydney	33 51.7 S	151 11.7	1896, Dec. 15-19	10 13 a	9 28.2E	26379	62 36.7 S	
7	Hobart	42 53 5 S	147 21.3	1897, Feb. 27-Mar. 3	2 46 p	10 05.6E	20448	72 10.4 S	
8	Tokyo	35 42.6 N	139 44.1	1898, Aug. 9-11	12 00 p	4 28.9W	29860	48 59.5 N	Voyage of the *Freundsberg* to East Asia; Lieut. Karl Mysz, Austrian Navy.
9	Chemulp-ho	37 28.5 N	126 37.2	1898, Oct. 13-15	10 01 a	4 57.0W	29905	53 10.2 N	
10	Singapore	1 17.8 N	103 53.2	1899, Feb. 1	.....	.....	.....	15 25.1 S	
11	Zanzibar	6 10.0 S	39 14.7	1898, Nov. 23-26	10 08 a	8 02.4W	29295	35 36.8 S	Voyage of the *Saida* to East Africa, Australia, and Sunda Is.; Ensign Stefan Benes von Czerchov, Austrian Navy.
12	Dar-es-Salaam	6 49.1 S	39 17.8	1898, Nov. 28	10 00 a	8 15.7W	.....	.....	
13	Zaudzi, Pamanzi I.	12 46.8 S	45 16.9	1898, Dec. 3-5	10 15 a	9 10.4W	26665	47 00.6 S	
14	Mozambique	15 00.9 S	40 44.7	1898, Dec. 18-20	10 15 a	11 24.5W	24349	49 39.2 S	
15	Lourenzo-Marques, Delagoa Bay	25 58.9 S	32 36.0	1899, Jan. 4, 5	10 30 a	23 11.4W	19782	58 54.1 S	
16	Bahia	13 00.7 S	321 28.6	1900, July 4	10 26 a	12 55.0W	32945	0 20.2 N	Voyage of the *Donau* around the globe; Ensign Virgil Sándor de Vist, Austrian Navy.
17	Port Belgrano	38 55.3 S	297 58.2	1900, Aug. 15	10 11 a	11 00.7E	26377	33 58.8 S	
18	Punta Arenas, Magellan Sts.	53 09.8 S	289 05.8	1900, Sept. 6	12 29 p	20 40.5E	.....	.....	
19	Port Corral, Valdivia	39 53.2 S	286 32.5	1900, Oct. 1	.....	.....	27572	39 15.2 S	
20	Valparaiso	33 01.9 S	288 22.0	1900, Oct. 19	11 00 a	14 30.9E	27301	31 07.8 S	
21	Iquique	20 12.3 S	289 49.6	1900, Nov. 16	12 21 p	10 05.0E	27507	13 20.0 S	
22	Callao	12 04.0 S	282 50.1	1900, Dec. 12	10 20 a	9 57.1E	29808	3 57.5 S	
23	Guayaquil	2 11.3 N	280 08.6	1900, Dec. 23	10 58 a	8 51.7E	32258	13 19.3 N	
24	Panama	8 54.8 N	280 28.1	1901, Jan. 6	10 12 a	4 55 1E	33120	32 23.9 N	
25	Punta Arenas, Costa Rica	9 58.8 N	275 10.0	1901, Jan. 13	10 04 a	6 07.1E	33276	32 56.1 N	
26	Acajutla, San Salvador	13 34.7 N	270 09.7	1901, Jan. 24	9 56 a	6 11.0E	33592	38 16.9 N	
27	Honolulu	21 18.6 N	202 08.5	1901, Mar. 13	10 05 a	10 20.9E	29659	39 32.7 N	
28	Batavia	6 06.1 S	106 53.3	1901, July 7	10 43 a	1 08.4E	36700	30 14.8 S	

magnetometer. Surface consists of primitive rocks covered with layer of red soil. *During the observation several severe earthquake shocks were felt.*

5. *Cooktown.* In the garden of the German consul. Soil, sand, covered with grass. Dip circle fifty meters south of magnetometer.

6. *Sydney.* On stone pier of the magnetic hut of the Sydney Observatory. Dip circle mounted in same place.

7. *Hobart.* In the court of the Observatory, in the line connecting a small observing house, then not in use, with south meridian mark, two thousand meters distant. Dip circle mounted in same place. Geological formation is primitive rocks covered with a thick earth layer grown over with grass.

8. *Tokyo.* The magnetometer comparisons between the Japanese and Austrian instruments were made in two tents (distant from each other about thirty steps) in the recreation ground in front of the Physical Institute of the University. The tent for the dip circle observations was about thirty steps north of magnetometer tent. The soil consists of alluvium covered with grass. [Karl Kailer (Erdmagnetische Reise beobachtungen, I. Heft) observed at same place in 1895.]

9. *Chemulp-ho* (*Corea*). In the vegetable garden on the estate of Mr.

Digitized by Google

Carl Wolter. The villa on the hill back of the town is designated on the harbor chart as "Meyer's house." Soil, loam, with thin layer of humus and loose earth. The rocks in the hill consist of marl and limestone.

10. *Singapore.* In the open place near the Master-Attendant's Office, along the right wall of the quay at the mouth of the Singapore river. Alluvial soil with coral sediment and sand. [Same place at which Karl Kailer observed in 1895.]

11. *Zanzibar.* In the meadow south of town.

12. *Dar-es-Salaam.* In the meadow of the governor's house.

13. *Zaudsi (on the I. Pamanzi near Mayotta).* In the large, open, flat place, but sparsely grown over.

14. *Mozambique.* Outside of town near Fort Sebastian.

15. *Lourenco-Marques (Delgoa Bay).* In meadow in front of the lighthouse on the Point Vermelha (Reuben Pt.)

16. *Bahia.* Outside of town, near the lighthouse, S. Antonio—a large open place, thickly sodded, with a few cocoanut trees. A limestone formation.

17. *Port Belgrano (Bahia Blanca.)* On a fairly solid sand dune on Punta Cigucaua.

18. *Punta Arenas (Magellan Strait).* Outside of town, on a hill southwest of Lookout Hill. Sod-covered soil.

19. *Port Corral (Valdivia).* On the rampart of the old fort. Sod-covered soil.

20. *Valparaiso.* In the court of the Marine Academy. Solid, somewhat rocky bottom.

21. *Iquique.* On the island, near lighthouse. Rocky bottom.

22. *Callao.* On the tongue of land, El Punta, near the abandoned workshops of the Pacific Steamship Company. Soil, firm sand and pebbles.

23. *Guayaquil.* North of the town, in a garden on a hill between Cerro de Sta. Anna and Cerro del Carmen. Firm, sod-covered soil.

24. *Panama.* On the Island Naos. On this island is an observing place on the grounds of the P. S. S. C., at the southeast point of the island. Soil, firm, grown over with grass.

25. *Punta Arenas (Costa Rica).* In a street not yet built up. Sod-covered soil.

26. *Acajutla (San Salvador).* On a hill. Soil, somewhat rocky, covered with sod.

27. *Honolulu.* In a large open place near the Government Office. The spot is marked by a stone with a metal plug in it.

28. *Batavia (Tanjong-Priok).* In a large meadow east of the coal depot. Solid grass sod.

It would have been desirable to have made the descriptions more explicit whenever possible, or marked the stations in some manner, so as to have made it possible to reoccupy in the future the *precise* point—a very essential matter for the deduction of the secular change from observations made in the same locality by different observers. It is also deemed preferable to make all magnetic observations, inclusive of the same station.

Digitized by Google

LETTER TO EDITOR

MR. WATSON'S COMPARISON AT KEW OBSERVATORY.

With reference to the note (Vol. 7, p. 99) on the abstract of Mr. Watson's paper in the "R. S. Proceedings," and to the foot-note attached thereto, I would point out that, subsequent to the publication of the abstract, Mr. Watson found that, "owing to a mistake in the corrections applied to the weights used in the silver depositions, the numbers . . . which appeared in the 'Proceedings of the Royal Society' (Vol. 69, p. 1) require correction." This correction (see "Phil. Trans.," Vol. 198 A, pp. 454–6) raises Mr. Watson's values dependent on the weights in question by some 6 γ or 7 γ, bringing his mean value for H, expressed in international units, into almost exact agreement with the corresponding mean from the Kew magnetometer. Mr. Watson himself (l. c., pp. 461–2) considers .001118 3 a more probable value for the electro-chemical equivalent of silver than the value .001118 accepted at present, and if the revised value he approves were accepted, it would increase the apparent difference between the results from the coil and magnetometer. It is hardly necessary to point out that until the electro-chemical equivalent of silver is really known to 5 significant figures—instead of to 4, as at present—any comparison of coils and magnetometers based on it can not lead to absolute final results. A similar remark applies to measurements based on an assumed E. M. F. for a Clark cell. At the same time, coil comparisons might greatly facilitate the attainment of definite conclusions as to the *differences* between magnetometers and their constancy,—subjects of interest, as to which our present knowledge is both scanty and uncertain. Before, however, we could feel assurance on this point it would be necessary to investigate the consistency of the results obtained with coils. Until several coils have been made, preferably by different makers, and several intercomparisons have been carried out under varied conditions, it might be premature to assume that the results obtained with them are free from all appreciable sources of uncertainty. Be this as it may, the method employed by Mr. Watson is in many respects so different from the ordinary one that the somewhat remarkable agreement at which he has arrived greatly encourages the belief that the determination of horizontal force in the usual way, by unifilar magnetometers, is free from any *large*, undetected source of error.

C. CHREE.

NATIONAL PHYSICAL LABORATORY, KEW OBSERVATORY, October, 1903.

Digitized by Google

NOTES

20. *The Gainsborough portrait of Franklin* reproduced, by permission in this number from the Alumni Register of the University of Pennsylvania, was presented in 1902 to the University by the graduating class of 1852 to mark the fiftieth anniversary of their graduation; it is hung in the Library. Franklin had taken an active part in the establishment of the University.

21. *The Journal has again been aided financially during the current year by a grant from the Hodgkins Fund of the Smithsonian Institution.*

22. *Munich Magnetic Observatory.* It is a pleasure to know that magnetic work is once again in progress at a place made famous by Lamont's work. *Dr. J. B. Messerschmidt*, formerly of the "Deutsche Seewarte," who has been in charge of the newly erected magnetic observatory since October 1, 1902, hopes soon to issue a report of the establishment of the observatory, including the results for 1899–1900. He is also contemplating a magnetic resurvey of Bavaria, which, owing to the work of Lamont over a half century ago, will prove especially valuable. Unfortunately, the site of the Observatory is not beyond the influence from electric car lines, so that minute variations in D and H will scarcely be discernible during the hours of traffic, and the vertical force instrument has had to be abandoned entirely.

23. *Heinrich von Wild.* We regret to be obliged to announce the death of the well-known magnetician HEINRICH VON WILD, after a long and severe illness, at Zürich, Switzerland, on September 5, 1902. A biographic notice and portrait appeared in Vol. IV, December issue.

It is understood that his widow, Madam R. von Wild (56 Englischviertel, Zürich, Switzerland), is willing to sell her husband's large library, bearing chiefly on meteorology, magnetism, meteorology and physics.

24. *Norwegian Polar Aurora Stations.* Professor Birkeland writes that the work of the four stations, Kaafjord (Norway), Dyrafjord (Iceland), Aksel Island (Spitzbergen), and Matotschkin-Schar (Novaja-Zemlja), is in good progress, and that about thirty stations are co-operating with him.

Digitized by Google

ABSTRACTS AND REVIEWS

MAGNETIC MEASUREMENTS IN A BALLOON.[1]

A short paper in correction and extension of the author's previous contribution on this subject (Ill. Aer. Mitt., Vol. 4, p. 137), already reviewed in these pages.[2] The value of balloon observations as compared with those made on mountains is first discussed, particularly with reference to their bearing on the question of the source of the Earth's magnetism. The experimental results obtained with the author's horizontal intensity variometer at different altitudes have been subjected by Professor Schmidt, of Gotha, to a more accurate computation, into which the variation of the magnetic elements with the latitude and longitude enter. The resulting value of the decrement of horizontal intensity with altitude is now 8.3 gamma per kilometer instead of 10 gamma, as formerly computed. The instrument has also been improved, so that its results are now accurate to within one gamma.

W. G. CADY.

[1] Zusatz zu meinem Aufsatze: "Magnetische Messungen im Ballon." Von DR. HERMANN EBERT. *Illustrirte Aeronautische Mittheilungen*, January, 1902.

[2] T. M., March, 1902.

THE ELECTRIC CHARGE ON A BALLOON.[1]

[1] Die elektrische Ladung des Luftballons, von DR. FRANZ LINKE. *Illustrirte Aeronautische Mittheilungen*, January, 1902.

Until recently it has been customary to regard the balloon as a non-conducting body, capable of retaining an electric charge. This view was also borne out experimentally. The matter is an important one, since all observations of atmospheric electricity made in a balloon are more or less in error if the balloon itself is at a different potential from the surrounding air. The assumption that the balloon is a non-conductor has been rendered impossible since the introduction, a few years ago, of the process of treating the covering of the balloon with calcium chloride. Tests made by Dr. Linke on the various parts of a balloon thus treated proved that even in direct sunshine it must be regarded as an electrostatic conductor. This is of practical importance, since the calcium chloride treatment removes the danger to balloon and occupants from electrical discharges; it also demands a new discussion of the subject from a theoretical standpoint. To this end, we assume, first, that the balloon starts at the potential V_1 of the ground—*i. e.*, under normal conditions, with a negative charge. If the balloon rises to a point where the air is at the potential V_2, then a quantity of electricity, $C(V_1-V_2)$, becomes free, where C is the capacity of the balloon. This disturbs the normal course of the equipotential surfaces, so that a collector or other electrical instrument does not assume the same potential that it would if the balloon were not present. If the balloon sinks, or if the ground at the start were positively charged, the electric charge yielded up has the opposite sign, and the effect on the collector is also in the opposite direction. Only when the balloon is

Digitized by Google

neither rising nor sinking is its effect on the collector zero (the author apparently does not consider the fact that the mere presence of the balloon as a large closed equipotential surface interposed in the electrostatic field must of itself sensibly alter the arrangement of neighboring surfaces). The dissipation of the charge on the balloon is hastened by the many corners and points, by the action of charged ions in the atmosphere, by air-currents, the action of the collector, and the throwing out of ballast. As the experiments presently to be described indicate, the effect is probably a very rapid one.

The method followed in testing this theory was a modification of that employed by Tuma in 1893. Attached to the car of a balloon were three water-droppers, from the outlets of which ran three chains, 8, 10, and 12 meters long, respectively. The collectors thus indicated the potentials prevailing at distances 8, 10, and 12 meters below the balloon. The collector carrying the 10-meter chain was connected to the outside of an aluminum-leaf electrometer, while by means of a commutator the other two collectors could be connected alternately with the leaf. Thus it was possible in rapid succession to measure the differences of potential between the layers of air at 8 and 10, or at 10 and 12, meters below the balloon. These two potential differences should be the same if the balloon exercises no disturbing influence. If the balloon passes from one region into another relatively positive, the longer pair of collectors (*i. e.*, 10 and 12 m.) should indicate the greater potential difference. This was fully borne out by the observations, which were made under a variety of conditions. When the balloon had remained for some time at nearly the same height, the two pairs of collectors indicated approximately the same difference of potential. These considerations probably explain certain apparent anomalies in Tuma's earlier observations. The author suggests that, where observations in atmospheric electricity are to be made from a balloon, a water-dropper with strong forced jet would be of advantage in bringing the balloon rapidly to the potential of the surrounding air.

In conclusion, a formula is derived for computing the total charge on a balloon, when the rate of ascent, fall of potential, and rate of electrical dissipation are given. W. G. CADY.

WESLEYAN UNIVERSITY, MIDDLETOWN, CONN., Sept. 10, 1902.

ELSTER'S AND GEITEL'S RESEARCHES ON THE RADIO-ACTIVITY AND THE CONDUCTIVITY OF THE AIR.[1]

Since their notable discovery that the atmosphere, under ordinary conditions, imparts radio-activity to negatively charged conductors, Professors Elster and Geitel have been actively engaged in investigating this and allied phenomena. Their results are of great interest and importance, furnishing a new factor in the study of atmospheric electricity.

In this abstract Professor Elster reports the following laws for the induced radio-activity imparted to metal wires in contact with the atmosphere: The imparted radio-activity, measured by a loss of charge electrometer, is pro-

[1] Résumé of verbal reports by Professors Elster and Geitel contained in *Separatabdruck aus den Sitzungs-Protocollen der luft-electrischen Commission der Delegierten Versammlung der Kartellierten Akademien zu Göttingen, am 15 und 16 Mai*, 1902. 8 pp., 13 x 20 cm.

Digitized by Google

portional to the length of the exposed wire; it is independent of the diameter if the diameter be less than 2 mm., and lightly increases with the diameter for larger wires; it is independent of the kind of metal and is independent of the potential at which the wire is kept, provided the potential is more than 2,000 volts (negative). With two hours' exposure the activity reaches its maximum. Twine rendered conducting works as well as wire.

For air in inclosed spaces the conductivity has a close connection with the radio-activity imparted to a negatively charged wire. In cellars both the conductivity and the imparted radio-activity are found to be many times higher than in upstairs rooms. In the open air the conditions are less simple, so that no simple relation has been found between the radio-activity and the conductivity. The maximum imparted activity was obtained during a light snowfall, the minimum under a cloudy sky and in fairly clear air. Frequently a minimum activity is found to occur with a maximum barometer height.

A wire stretched between two houses and 20 meters above ground collected very little radio-activity, the conclusion being that the layer of air just next the Earth is continually traversed by weak Becqueral rays.

Continuous measurements at permanent stations, as well as measurements at places as climatically different as possible, are highly desirable, and for such measurements the simple and portable apparatus of Elster and Geitel has been designed. The outfit consists of (1) a Zamboni's pile of 2,300 volts P. D.; (2) a portable electroscope on Braun's principle, with sodium dryer; (3) a wire gauze cylinder, which can be introduced into the test cylinder of the conductivity, with 20 meters of wire wound on it; (4) two wire holders of ebonite, with sodium drying arrangement, which preserve their insulation even in the dampest weather; and, finally, a case for the whole.

In regard to experiments, made in conjunction with Professor Geitel, on the question of positively charged conductors becoming radio-active from the atmosphere, Professor Elster reports that in cellar air, of relatively high conductivity, a positively charged conductor becomes about $\frac{1}{10}$ as radio-active as a negatively charged one. In the open air no definite results could be obtained. Thorium compounds have not been found to impart activity to positively charged conductors in the neighborhood, which suggests to Professor Elster a specific difference between the imparted activity from the atmosphere and that from thorium.

Professor Geitel reports that he and Professor Elster find that in atmospheric conductivity experiments the presence of other electric fields than that due to the test charge has quite a marked effect on the results, a potential gradient of less than one volt per cm. sufficing to affect the measurements. This has an application in measurements in the open air, where the Earth's field is always present. It was also found that differences in the conductivity for positive and negative charges need not be due to the excess of ions of one sign over those of the other, but may be due to the influence of the Earth's field.

Many experiments were made with a view to discovering the source of the radio-active properties of the atmosphere. No radio-activity was to be detected in the brick or stone used in the walls of cellars where the air was of abnormal conductivity. Hydrogen peroxide was suspected of having some-

Digitized by Google

thing to do with the imparting of activity to charged conductors, but, on testing a piece of twine soaked in the peroxide, and exposed as usual, the amount of activity was found to be the same as when no peroxide was used. Nor does hydrogen peroxide have any influence on the conductivity of air. It was thought that perhaps large masses of water might impart radio-activity to charged conductors, as well as large masses of air, and, since in the electrolysis of uranium solution the kathode becomes radio-active, a wire 20 meters long was laid in water and made the kathode for the passage of one to two amperes for 24 hours. Upon removal the wire showed no activity. The reviewer would suggest that it would be well to make the experiment with the wire as *anode*, as he has found that in the electrolysis of thorium solutions it is the anode which becomes radio-active, and that the active substance which is present in the atmosphere, and which may be present in water, resembles the emanation from thorium rather than from uranium compouuds.

The attention of other observers is called to the fact that the radio-activity imparted by the air affects to some extent the working of apparatus for measuring atmospheric conductivity, so that after a while the results are too high. New apparatus invariably gives lower values for conductivity than old apparatus.

Finally, a contrivance for increasing the convenience and accuracy of reading the Exner electroscope is described. The front glass wall of the instrument does not carry a paper scale, but an arc of its lower inner surface is silvered. In front of this silvered surface is a milk glass scale, placed at such a distance that the image of the scale, reflected from the silvered surface, appears exactly in the plane of the front edge of the leaves. Parallax is thus avoided, and the position of the leaf read on the image of the scale.

GEO. B. PEGRAM.

COLUMBIA UNIVERSITY PHYSICAL LABORATORY, NEW YORK.

DETERMINATION OF THE DISTRIBUTION COEFFICIENT.

In the autumn of 1897, Professor Ciro Chistoni made a series of observations near Modena to test the accuracy of various approximate formulæ for determining the distribution coefficient of a magnetometer (coefficiente magnetometrico).[1]

In the fundamental expression for computing the value of $\frac{H}{m}$ from observations of deflections, the factor $\left(1 + \frac{P}{r^2} + \frac{Q}{r^4} + \dots\right)$, depending upon the distribution of magnetism in the two magnets, may theoretically be simplified if the dimensions of the two magnets bear certain relations to each other. If the lengths of the deflecting and deflected magnets are in the ratio of 1.22 to 1, the coefficient P becomes nearly zero; if the ratio is 1 to 0.47, the coefficient Q becomes nearly zero. In the instrument used by Chistoni the latter condition was nearly satisfied, and he determined P from deflections at two distances, assuming the coefficients involving higher powers of r to be zero.

[1] Ricerche sperimentale sul coefficiente magnetometrico. Nota di CIRO CHISTONI, Torino, 1900. [Accademia Reale delle Scienze di Torino, Anno, 1899-1900.]

Digitized by Google

The instrument was provided with a long collimating magnet about 1 cm. in diameter and 10 cm. long, and two short magnets 4.7 and 5.10 cm. long, respectively. The deflection bar was one meter long, with marks at 23, 26, 30, 34, 39, and 44 cm. from the middle toward either end. The resulting values of P, using no approximations, are shown in the following table, the first value being the mean of 11 results, each of the others of 10:

Deflecting magnet	Suspended magnet	r_1 cm	r_2 cm	P	Deflecting magnet	Suspended magnet	r_1 cm	r_2 cm	P
1503	8902	26	34	25.86	1503	505	26	34	24.53
do	do	30	39	25.12	do	do	30	39	24.66
do	do	34	44	25.03	do	do	34	44	24.74
Mean,				25.34	Mean,				24.64

These results justify the dropping of the terms involving higher powers of r than the second.

Chistoni then repeated the computation of the first set of observations, making use of various approximations. The results are shown in the following table. The values in the column headed P are obtained from the rigorous formula, allowing for the effect of induction and the differences in temperature of the bar and magnet for the two deflection distances. For the first approximation, P_1, the temperature differences were neglected; for the second, P_2, use was made of the formula

$$\log P = \log C + \log [(\log \sin \phi_1 - \log \sin \phi_2) + \log c]$$

in which

$$C = -\frac{r_1^2}{\left(\frac{r_1^2}{r_2^2} - 1\right) \log e}$$

and $\log c = \log [1 + a(t_1 - t_2)] + \log [1 + hH(\sin \phi_1 - \sin \phi_2)] + \log \frac{r_1^3}{r_2^3}$

ϕ^1 and ϕ^2 being the deflection angles for the distances r_1 and r_2, and t^1 and t^2 the corresponding temperatures; the third, P_3, by assuming $t_1 = t_2$ in the above formula; and the fourth, P_4, by neglecting the induction correction:

P	P_1	P_2	P_3	P_4	t_1 °	t_2 °
26.15	26.68	25.35	25.83	25.11	25.90	26.48
26.54	27.08	25.70	26.20	25.49	27.52	28.12
25.98	26.15	25.22	25.34	24.63	28.20	28.35
25.25	25.26	24.48	24.48	23.76	28.87	28.87
24.13	24.33	23.41	23.62	22.90	30.45	30.70
26.41[1]	26.50	25.60	25.68	24.96	28.32	28.40
23.92	23.30	23.20	22.64	21.93	27.38	26.70
26.59	26.59	25.69	25.75	25.04	29.08	29.15
26.01	26.10	25.18	25.30	24.59	30.22	30.35
26.38	26.19	25.54	25.38	24.66	29.60	29.38
27.14	26.34	26.26	25.52	24.82	27.87	26.95
Mean, 25.86	25.87	25.06	25.07	24.35	28.49	28.50

[1] This value was erroneously given as 23.91 by Chistoni.

Digitized by Google

A comparison of these results shows that the temperature correction may be neglected without seriously affecting the accuracy of the result, but that the use of the approximate formula gives too small a value of P. The effect of neglecting the correction for induction is also considerable, though not so great as the table would indicate. Thus for r = 26 cm. the value of $\log\left(1 + \frac{P}{r^3}\right)$ is 0.01639 for $p = 25.06$ and 0.01591 for $P = 24.35$; but the latter includes the correction for induction. To render the two comparable, the former must, therefore, be combined with the induction correction, becoming 0.01606.

In the United States Coast and Geodetic Survey a modified form of the approximate formula given above has been in use for several years.[1] In the regular field work, as well as in special observations to determine the value of the distribution coefficient, the deflections are made at two distances, in the order indicated below, so that the temperature of bar and magnet and the value of H may be assured the same for the two distances.

Deflector East of Suspended Magnet			Deflector West of Suspended Magnet		
No	North End of Deflector	Distance	No	North End of Deflector	Distance
1	East	30 cm	5	West	30 cm
2	East	40	6	West	40
3	West	40	7	East	40
4	West	30	8	East	30

It was recognized that this approximate formula gives too small results, and a simple method was devised for correcting them, best shown by an example. Chistoni's fourth observation gives by his approximate formula $P = 24.48$, the value of $(\log A_1 - \log A_2)$ being 0.00653. The values of $\log\left(1 + \frac{P}{r^3}\right)$ for the two distances used are 0.01543 and 0.00909, the difference being only 0.00634, whereas it should be the same as $(\log A_1 - \log A_2)$. A close approximation to the true value of P is found by the proportion $\frac{P}{24.48} = \frac{.00653}{.00634} = 25.21$. This agrees very closely with the value, 25.25, obtained by using the rigid formula, and a second trial, $\frac{P}{25.21} = \frac{.00653}{.00652}$, gives that value exactly. By this method a computation of the individual values of P is unnecessary, the mean value being found directly from the mean value of $(\log A_1 - \log A_2)$, provided the same two distances have been adhered to.

D. L. HAZARD.

U. S. COAST AND GEODETIC SURVEY, WASHINGTON, D. C.

ASYMMETRY IN MAGNETOMETER DEFLECTIONS.

In the "Annalen der Physik," No. 5, 1902, pp. 348–366, F. Richarz and P. Schulze discuss several interesting cases of asymmetric oscillations, includ-

[1] Cf. TERRESTRIAL MAGNETISM, Vol. VI, No. 2, p. 79.

Digitized by Google

ing the oscillations of a unifilar magnetometer magnet deflected from the meridian, in its equilibrium position, by torsion. In the same journal, No. 7, pp. 714–719, P. Schulze investigates for two particular cases the asymmetric deflections of a unifilar magnometer magnet deflected initially by torsion from the meridian. Let γ denote the initial angular deviation of the magnet's axis from the meridian produced by rotating the torsion head through the angle ω, and let H denote the horizontal component of the Earth's magnetic field.

(1) If a short magnet with moment M^1 is placed with its center at distance e from the center of the magnetometer magnet in the first position of Gauss—*i. e.*, with its axis passing through the center of the suspended magnet, and making an angle $90° \pm \gamma$ with the magnetic meridian—the magnetometer magnet will be deflected through an angle α such that, if small,

$$\alpha = \pm \frac{-\frac{M^1}{e^3}}{H\cos\gamma + \frac{H\sin\gamma}{\omega-\gamma}} + \frac{\frac{H\sin\gamma}{2}\left(\frac{M^1}{e^3}\right)^2}{\left(H\cos\gamma + H\frac{\sin\gamma}{\omega-\gamma}\right)^3} \qquad (1)$$

approximately, the + sign applying to deflections in the direction of torsion and the — sign to deflections in the opposite direction. For given values of M^1 and e the deflection is thus greater when in the direction of torsion.

(2) Similarly, if a small deflection β is produced by a slight variation dH in H, as in the horizontal intensity variometer,

$$\beta = \mp \frac{dH}{H\left(\operatorname{cotan}\gamma + \frac{1}{\omega-\gamma}\right)} + \frac{\frac{H}{2}dH^2}{\left(H^2\operatorname{cotan}\gamma + \frac{1}{\omega-\gamma}\right)^3} \qquad (2)$$

approximately; β, for a given absolute change in the intensity, being thus greater when dH is negative—*i. e.*, when the deflection is in the direction of torsion. The asymmetric term is proportional to $\left(\operatorname{cotan}\gamma + \frac{1}{\omega-\gamma}\right)^{-3}$, so that the asymmetry for a given value of γ is greater the greater $\omega - \gamma$; *i. e.*, the finer and longer the suspension fiber, or the more sensitive the instrument. The considerable magnitude which the asymmetry may attain in practice is shown by the following example: If $\gamma = \pi/2$, $\omega - \gamma = 10\pi$, $H = 0.18844$, and $dH = \pm 0.00040$, then, by (2),

$$\beta + = +0.00737 \text{ radian}$$

when dH is negative; and

$$\beta - = -0.00597 \text{ radian}$$

when dH is positive, the difference between the two deflections being some 20%. Three methods of calibrating the variometer, based on the equations developed in the two papers, and taking account of the asymmetry, are suggested.

S. J. BARNETT.

LELAND STANFORD UNIVERSITY, CALIFORNIA.

Digitized by Google

MAGNETIC OBSERVATIONS IN IRELAND.[1]

As far back as 1887, the late Professor FitzGerald, of Trinity College, Dublin, expressed a desire for a series of magnetic observations to be made in Ireland. Mr. J. E. Cullum volunteered to undertake the work and began observations in a wooden hut erected in the observatory grounds in Valencia Island, using an old-pattern unifilar by Jones and a dip circle by Barrow, loaned by Trinity College. The results of the first few years of this series were published in the "Proceedings of the Royal Irish Academy." The observations were continued until the end of 1896, when the instrumeuts were recalled by Trinity College.

Sufficient interest was shown in the work, however, to warrant its re-establishment on a more permanent basis. A new set of instruments was secured (magnetometer No. 139 and dip circle No. 118, both made by Dover) and observations were begun in January, 1899, in a wooden observing-house erected in the field north of the observatory at Cahirciveen.

The observatory is on an arm of Valencia Harbor in latitude 51° 56′ and longitude 10° 15′ West of Greenwich. Observations are made on two days at the middle of each month. Declination is determined at about 10^h A. M., dip at 11^h 45^m A. M. and 1^h 25^m P. M., and horizontal intensity at 11^h A. M. and 3^h P. M. The mean values for each of the three years are tabulated below:

Year	D	I	H	Z	W
	° ′	° ′	γ	γ	γ
1899	21 35.0 W	68 33.0	17739	45164	48504
1890	30.0	29.6	765	082	460
1901	27.7	26.3	801	048	438

D. L. HAZARD.

[1] Report of Absolute Magnetic Observations at the Valencia Observatory, Cahirciveen, County Kerry, Ireland, 1899, 1900, 1901, by J. E. Cullum. Pro. Roy. Soc. Vol. LXX, No. 462.

Digitized by Google

ASTOR, LENOX AND
TILDEN FOUNDATIONS

TERRESTRIAL MAGNETISM
AND
ATMOSPHERIC ELECTRICITY

Digitized by Google

Digitized by Google

TERRESTRIAL MAGNETISM

AND

ATMOSPHERIC ELECTRICITY

AN INTERNATIONAL QUARTERLY JOURNAL

Conducted by

L. A. BAUER,

Coast and Geodetic Survey, Washington, D. C.

With the Assistance of

J. S. AMES
Johns Hopkins University, Baltimore

J. ELSTER
Wolfenbüttel, Germany

H. GEITEL
Wolfenbüttel, Germany

D. L. HAZARD
Coast and Geodetic Survey, Washington

G. W. LITTLEHALES
Hydrographic Office, Washington

A. McADIE
Weather Bureau, San Francisco

TH. MOUREAUX
Observatoire, Parc St. Maur

H. F. REID
Johns Hopkins University, Baltimore

ADOLF SCHMIDT
Magnetisches Observatorium, Potsdam

A. SCHUSTER
Owens College, Manchester

Foreign Councilors

A. W. RÜCKER
England

W. VON BEZOLD
Germany

E. MASCART
France

M. RYKATCHEW
Russia

VOLUME VIII

MARCH–DECEMBER, 1903

THE JOHNS HOPKINS PRESS
BALTIMORE, MARYLAND
1903

Digitized by Google

293713

Digitized by Google

CONTRIBUTORS OF ARTICLES AND REVIEWS

C. ABBE,	Washington, District of Columbia
M. MORENO Y ANDA,	Tacubaya, Mexico
R. AMUNDSEN,	Christiania, Norway
L. A. BAUER,	Washington, District of Columbia
W. VAN BEMMELEN,	Batavia, Java
KR. BIRKELAND,	Christiania, Norway
G. W. CADY,	Middletown, Connecticut
C. CHREE	Richmond, England
C. C. FARR,	Christchurch, New Zealand
J. A. FLEMING,	Cincinnati, Ohio
J. W. FROLEY,	Washington, District of Columbia
D. L. HAZARD,	Washington, District of Columbia
H. HILDEBRAND HILDEBRANDSSON,	Upsala, Sweden
W. C. HODGKINS,	Washington, District of Columbia
W. KESSLITZ,	Pola, Austria
J. M. KUEHNE,	Austin, Texas
R. E. NYSWANDER,	Washington, District of Columbia
G. B. PEGRAM,	New York City
H. F. REID,	Baltimore, Md.
A. L. ROTCH,	Blue Hill Observatory, Massachusetts
L. G. SCHULTZ,	Cordoba, Argentine Republic
H. F. SKEY,	Christchurch, New Zealand
G. F. STRADLING,	Philadelphia, Pennsylvania
W. SUTHERLAND,	Melbourne, Australia
W. F. WALLIS,	Cheltenham, Maryland

Digitized by Google

TABLE OF CONTENTS

MARCH 1903

PORTRAIT OF LORD KELVIN, - - - - - *Frontispiece*, [Plate I.]

DIE BEABSICHTIGTE NORWEGISCHE EXPEDITION NACH DEM MAGNETISCHEN NORDPOL, - - - - - - *Roald Amundsen* 1

MEAN VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES, *D. L. Hazard* 7

THE CHRISTCHURCH MAGNETIC OBSERVATORY, NEW ZEALAND, *C. C. Farr* 9

THE MAGNETIC OBSERVATORIES OF THE UNITED STATES COAST AND GEODETIC SURVEY IN OPERATION ON JULY 1, 1902, *L. A. Bauer and J. A. Fleming* 11

TROMHOLT'S CATALOGUE OF NORWEGIAN AURORAS, - *C. Abbe* 30

BIOGRAPHICAL SKETCH OF LORD KELVIN, - - - - - - - 33

NOTES, - - - - - - - - - - - - - - - - 35

ABSTRACTS AND REVIEWS: *A. L. Rotch*, Terrestrial Magnetism and Atmospheric Electricity at the International Aeronautical Congress, 1902. *Chauveau*, Recherches sur L'Electricite Atmospherique; *Logeman*, Observations of Electrical Conductivity of Atmosphere at Cape Town; *Gockel*, Atmospheric Electricity Observations; *Homma*, Studies in Atmospheric Electricity, L. G. SCHULTZ. *Steiner*, Magnetic Observations about Lake Balaton, Hungary, 1901, J. A. FLEMING. *Ashworth*, Experimental Researches on Drawn Steel. *Pola*, Magnetic Observations at Pola Observatory, W. F. WALLIS. *Elster*, Photographic Effects of Becquerel Rays in the Atmosphere, G. B. PEGRAM, - - - - - 37

RECENT PUBLICATIONS, - - - - - - - - - - - 48

JUNE, 1903

PAGE

PORTRAIT OF J. J. THOMSON, - - - - - *Frontispiece*, [*Plate II.*]

THE CAUSE OF THE EARTH'S MAGNETISM, - - *W. Sutherland* 49

AN ANALYSIS OF THE RESULTS FROM THE KEW MAGNETOGRAPHS ON QUIET DAYS DURING 1890–1900 - - - - - *C. Chree* 53

Digitized by Google

ADOLF SCHMIDT'S CHARTS OF THE EARTH'S MAGNETIC COMPONENTS FOR 1885 - - - - - - - - - - - - - 56

RESULTS OF MAGNETIC OBSERVATIONS IN THE UNITED STATES UP TO JUNE 30, 1902, - - - *L. A. Bauer and D. L. Hazard* 61

LIFE AND WORK OF BENJAMIN FRANKLIN, - - - - - - - 65

LETTERS TO EDITOR: Discontinuance of Co-operation in Magnetic Work with the British Antarctic Expedition, *H. F. Skey;* Continuance of International Co-operation in Rapid Registrations during Special Terms, *L. A. Bauer;* Concerning Observations of Terrestrial Magnetism and Clouds Carried out at the Norwegian Stations, 1902–3, *Kr. Birkeland;* Some Magnetic Observations in Mexico, *M. Moreno y Anda*, - - - - - - - - - - 73

BIOGRAPHICAL SKETCH OF J. J. THOMSON, - - - - - - - 77

NOTES, - - - - - - - - - - - - - - - - - 79

ABSTRACTS AND REVIEWS: *Lorenz*, Sichtbare und Unsichtbare Bewegungen, G. F. STRADLING. *Elster and Geitel*, On the Radio-activity of Ground Air; *H. Ebert*, The Concentration of Radio-active Emanations in Liquid Air, G. B. PEGRAM. *Elster and Geitel*, Messungen der Elektricitätszerstreuung in der freien Luft; *Le Cadet*, Etude de l'electricité atmosphérique au sommet du Mont Blanc; *Gockel*, Über Elektricitätszerstreuung bei nebeligem Weiter, L. G. SCHULTZ. *Chwolson's*, Lehrbuch der Physik, W. G. CADY. *Bauer*, Second Report on Magnetic Work in Maryland. *Cagni and Palazzo*, Magnetic Observations in the Bay of Teplitz, J. M. KUEHNE. *Pomorseff's* Absolute Determinations of the Elements of Terrestrial Magnetism, W. C. HODGKINS. Isoclinic and Isogonic Lines in Mindanao Islands, D. L. HAZARD. Magnetic Observations at Zi-ka-wei in 1900, W. F. WALLIS, - 82

SEPTEMBER, 1903

PORTRAIT OF STEPHEN JOSEPH PERRY, - - *Frontispiece*, [*Plate III.*]

THE PHYSICAL DECOMPOSITION OF THE EARTH'S PERMANENT MAGNETIC FIELD. NO. III.

a. The Earth's Total Magnetic Energy.
b. The Seat of the Principal Cause of the Secular Variation.
c. On the Improvement of the Gaussian Theory, *L. A. Bauer* 97

BESCHREIBUNG DES NEUEN MAGNETISCHEN THEODOLITEN "BAMBERG," NR. 7904, AM MAGNETISCHEN OBSERVATORIUM IN POLA, *W. Kesslitz* 130

LUNAR DIURNAL VARIATION AS OBTAINED AT THE CHELTENHAM MAGNETIC OBSERVATORY FROM A SINGLE COMPLETE LUNATION DURING FEBRUARY, 1903, - *L. A. Bauer and R E. Nyswander* 144

Digitized by Google

SECOND INTERNATIONAL SEISMOLOGICAL CONFERENCE AT STRASSBURG, *H. F. Reid* 147

BIOGRAPHICAL SKETCH OF STEPHEN JOSEPH PERRY, - - - - - 150

RECENT PUBLICATIONS, - - - - - - - - - - - - - 152

DECEMBER, 1903

PAGE

OBSERVATORIO MAGNETICO Y METEOROLOGICO DE LA ISLA DE "AÑO NUEVO," - - - - - - - - - *Frontispiece, [Plate IV.]*

THE DIURNAL FIELD OF MAGNETIC DISTURBANCE, *W. van Bemmelen* 153

ATMOSPHERIC ELECTRICITY AND TERRESTRIAL MAGNETISM AT THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1903, - - - - - - - - - - - - *A. L. Rotch* 175

EARLY HISTORY OF MARINER'S COMPASS, AND EARLIEST KNOWLEDGE OF THE MAGNETIC DECLINATION ACCORDING TO BERTELLI, *D. L. Hazard* 179

LETTER TO EDITOR: REQUEST FOR LIST OF MAGNETICALLY CALM DAYS, - - - - - - *H. Hildebrand Hildebrandsson* 184

MAGNETIC ELEMENTS DETERMINED BY P. COLIN IN MADAGASCAR, *J. W. Froley* 185

NOTES: MISCELLANEOUS, AND CONTINUANCE OF SPECIAL RAPID REGISTRATION OBSERVATIONS, - - - - - - - - - - 188

ABSTRACTS AND REVIEWS, - - - - - - - - - - - 190

LIST OF RECENT PUBLICATIONS WITH BRIEF ABSTRACTS, - - - 194

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX
AND TILDEN FOUNDATIONS.

Digitized by Google

Kelvin

Digitized by Google

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VIII MARCH, 1903 NUMBER 1

DIE BEABSICHTIGTE NORWEGISCHE EXPEDITION NACH DEM MAGNETISCHEN NORDPOL.[1]

VON ROALD AMUNDSEN, Leiter der Expedition.

Wenn ich dem für mich so ehrenvollen Ersuchen der Gesellschaft für Erdkunde, über meine beabsichtigte Reise einige Angaben zu machen, gern und mit bestem Danke Folge leiste, so geschieht dies in dem Bewusstsein, dass es für mich nur von dem grössten Nutzen sein kann, vor so hervorragenden Fachleuten meine Pläne zu entwickeln. Ich möchte deshalb die Herren bitten, mir jedes Bedenken gegen das Eine oder das Andere in meinem Vorhaben rückhaltslos zu äussern.

In schwierigen Verhältnissen kann oft ein guter Rath von weittragender Bedeutung sein. Meine Theilnahme an der antarktischen Expedition der Belgica gab mir die erste Veranlassung zu dem Projekt.

Es war ja auf jener Expedition beabsichtigt, zum magnetischen Südpol zu gelangen und die Ausrüstung an magnetischen Instrumenten war dementsprechend eine recht gute. Da jedoch die Expedition zu spät von Süd-Amerika aufbrach, war es nicht mehr möglich über Australien bis in die Gegend des magnetischen Südpols vorzudringen. Wir fuhren von Süd-Amerika direkt nach

[1]Einen Vortrag gehalten in der Gesellschaft für Erdkunde, Berlin, December 1902.

Digitized by Google

Süden, sassen dann bald im Eise fest und hatten in dieser Situation Zeit und Musse genug, um über andere Unternehmungen nachzudenken. Da ich mich an den magnetischen Messungen auf der Belgica betheiligte, wollte ich die gewonnenen Erfahrungen zu einer Erforschung des magnetischen Nordpols weiter verwerthen. Ich habe mich aber bei meinem Vorhaben nur von dem einen Gedanken leiten lassen, womöglich der Wissenschaft einigen Nutzen zu leisten, und aus diesem Grunde einen solchen Reiseweg in Aussicht genommen, dass ein Erfolg möglichst gesichert wird.

Es liegt mir deshalb fern, unter grossen Schwierigkeiten und Gefahren neue Länder zu entdecken oder vielleicht gar zum astronomischen Nordpol zu gelangen. Wenn ich überhaupt den Wunsch hätte, diesen Pol zu finden, so hätte ich ihn sicher nur deshalb, um damit allen—ich möchte sagen, sportmässigen—Expeditionen dorthin ein Ende zu machen.

Nach der Rückkehr der Belgica wandte ich mich im September 1900 an den Direktor der deutschen Seewarte, Herrn Geheimrath von Neumayer, und legte ihm meinen Plan vor, in der Gegend des magnetischen Nordpols magnetische, meteorologische und geologische Beobachtungen auszuführen. Herr Geheimrath stimmte meinem Plan vollständig zu und gab mir während eines Aufenthalts von zwei Monaten an der Seewarte in seiner allbekannten Liebenswürdigkeit die beste Unterweisung, welche ich haben konnte. Ich finde nicht die Worte, um meine warmen Gefühle grösster Dankbarkeit für Herrn Geheimrath von Neumayer zum rechten Ausdruck zu bringen. Auf seinen Rath bestellte ich ein magnetisches Reiseinstrument nach seiner Construktion beim Mechaniker Saemann in Hamburg und ein Inclinatorium bei Dover in Kent.

In Norwegen und Schweden äusserten sich die Herren Prof. Nansen und Prof. Geelmuyden ebenfalls sehr günstig über mein Vorhaben.

Im Jahre 1901 kaufte ich dann ein kleines Schiff — Gjöa genannt—für arktische Schifffahrt speciell gebaut.

Um die Eigenschaften des Schiffes gründlich kennen zu lernen, und eventuell noch geeignete Abänderungen zu treffen, unternahm ich mit der Gjöa eine sechsmonatliche Reise nach Novaja Zemblja, Spitzbergen und Grönland. Gleichzeitig machte ich oceanographische Untersuchungen in dem Grönländischen Polarstrom als Abschluss der gleichartigen Beobachtungen von Herrn Prof. Nansen auf dem Fram 1903–1906.

Digitized by Google

Im Juni und Juli 1902 war ich in Wilhelmshaven, um die Constanten meiner Instrumente zu bestimmen.

Den Herren Geheimrath Börgen und Prof. Stück bin ich ebenfalls für ihre grosse Unterstützung, welche sie mir andauernd zu Theil werden liessen, zu höchstem Danke verpflichtet.

Zur weiteren Einübung führte ich dann mit meinen Instrumenten in Gemeinschaft mit Herrn Axel Steen an verschiedenen Orten in Norwegen magnetische Messungen aus. An Herrn Prof. Schmidt hatte ich mich bereits früher um Rath gewandt, damit ich in kompetentester Weise darüber unterrichtet war, welche Messungen ich auszuführen hatte, um ihnen vom theoretischen Standpunkt aus den grössten Werth zu verleihen. Da ich beabsichtige, auch magnetische Registrirungen mit Instrumenten nach Eschenhagen durchzuführen, suchte ich Herrn Prof. Schmidt am magnetischen Observatorium zu Potsdam auf, um die Instrumente zu bestellen und gleichzeitig die Constanten der magnetischen Instrumente, welche bei der letzten Fram Expedition benutzt wurden und welche ich ebenfalls zu verwerthen gedenke, neu zu prüfen.

Auf den Rath des Herrn Prof. Schmidt gedenke ich die Basis-Station—von der aus dann kleinere Expeditionen unternommen werden sollen—dem magnetischen Pol nicht allzu nahe zu errichten, damit daselbst alle magnetischen Elemente noch mit *grösserer* Sicherheit bestimmt werden können und damit besonders die Veränderlichkeit der Declination, genaue Messungen nicht gar zu sehr erschwert.

Ich werde daselbst die Declination, Horizontal-Intensität und Vertical-Intensität ganz in der Weise registriren, wie sie von Herrn Prof. Eschenhagen im "Terrestrial Magnetism" beschrieben ist. Die drei Instrumente stehen hintereinander, erhalten von einer Lampe Licht und registriren dann ihren Stand zugleich auf dem photographischen Papier einer Walze. Nur wird es sich für meine Zwecke empfehlen, die Entfernungen der Instrumente etwas anders zu wählen.

Die absoluten magnetischen Messungen werden während der Winterzeit mit zwei Reiseinstrumenten, einem Fox Apparat und einem Erdinductor nach Wild-Eschenhagen ausgeführt werden. In den kleineren Expeditionen werde ich nur das eine Reiseinstrument und vielleicht auch den Fox Apparat mitnehmen.

Wie ich dies bereits vor einem Jahre in einem Vortrage in Christiania hervorgehoben habe, werde ich mich im wesentlichen

Digitized by Google

darauf beschränken müssen, den magnetischen Pol in einem beträchtlichen Abstand von mindestens 200 km. zu umkreisen, da die Beobachtungen in nächster Nähe des Pols zu unsicher sein werden und zu grossen Täuschungen Veranlassung geben könnten. Die Messungen würden eigentlich nur als Local-Untersuchungen zu bezeichnen sein, welche um so weniger allgemeinen Werth haben, als daselbst infolge der grösseren Total-Intensität die Local-Störungen voraussichtlich recht erheblich sein werden und infolge des geringen absoluten Werthes der Horizontal-Intensität viel mehr zur Geltung kommen als anderswo. Genaue Messungen würden dort auch mit mancherlei Schwierigkeiten mehr instrumenteller Natur verknüpft sein; das Mess-Instrument müsste im grossen und ganzen mehr als Local-Variometer ausgestattet sein.

Aus instrumentellen Gründen werde ich zur grösseren Sicherheit eine Anzahl Magnete von verschiedenstem Moment mitnehmen. Dieselben sollen so in eisernen Behältern verpackt sein, dass sie ihre Momente erfahrungsgemäss sehr constant erhalten. Dann bin ich in der Lage, die Horizontal-Intensität entweder durch Ablenkungen oder durch Schwingungen allein zu messen.

Messungen ersterer Art werden besonders während der Schlitten-Expeditionen vorzuziehen sein, während sich der Anschluss meiner Basis-Station an Potsdam hinsichtlich der Horizontal-Intensität vielleicht am besten durch Schwingungs-Beobachtungen ausführen lässt. Ich beabsichtige aber etappenweise von hier aus bis zu meiner Station Messungen auszuführen, um die Ablenkungs-Constanten von Magneten, welche sich hier wegen der kleinen Ablenkungs-Winkel nicht mit genügender Sicherheit bestimmen lassen, unterwegs zu ermitteln.

Die Gjöa, das Expeditionsschiff, ist, wie gesagt, nur klein, aber gerade dadurch wie auch durch ihre starke Bauart besonders für die Eisregion geeignet; ich hoffe mit ihr leichter als mit einem grösseren Schiffe durch die schmalen Fahrstrassen jener Gewässer zu kommen, welche ich durchforschen will. Das Schiff ist 70 Fuss lang, 20 Fuss breit und hält 48 Registertons, ich habe es aber noch durch schwere Holz- und Eisenbalken verstärken lassen. Auch ist es jetzt mit einem kleinen Petroleummotor versehen und läuft mit diesem etwa 4 Knoten in der Stunde. 30,000 Liter Petroleum in eisernen Behältern sollen zur Heizung, zum Kochen und als Triebkraft für den Motor dienen. Das Petroleum wird aber grossenteils durch schottische Walfishfänger bis in die Nähe der Gegend gebracht, wo ich voraussichtlich zunächst überwintern werde.

Digitized by Google

Proviant nehme ich für 4–6 Jahre mit, sowie eine möglichst gute Ausrüstung für eine Polar-Expedition.

Die Besatzung wird aus acht Mann bestehen, von denen zwei—ein Assistent und ich—im wesentlichen die magnetischen Arbeiten übernehmen, während ein dänischer Marine-Officier hauptsächlich geologische Studien machen wird.

Von Christiania werde ich voraussichtlich am 15. April 1903 aufbrechen. In Godhavn, auf der Insel Disco, auf der Westseite von Grönland, will ich mich mit Polarhunden versehen und magnetische Messungen ausführen. Solche Messungen sollen weiterhin an allen Orten, wo es möglich ist, angestellt werden, damit ich daraus auf die gegenwärtige Lage des magnetischen Nordpols Schlüsse ziehen kann. Wie mir mehrere Walfischfahrer mittheilten, fangen bereits in der Lancaster Strasse die besten Compasse von William Thomson an, ganz unzuverlässig zu werden.

Nach den bisherigen Ueberlegungen werde ich die Basis-Station am Leopold Hafen auf Nord Somerset einrichten. Da jedoch für die Wahl dieser Station mancherlei mitspricht, worüber ich vorläufig selber nichts Näheres weiss, kann ich natürlich keine ganz bestimmten Angaben über die Lage dieser Station machen. Auf jeden Fall möchte ich versuchen, im Sommer 1904 durch schottische Walfischfahrer, welche diesen Hafen gewöhnlich aufsuchen, Nachricht von mir nach Europa gelangen zu lassen. Auf der Station wird im Spätsommer und während des Winters mit der Einrichtung, sowie mit den absoluten Messungen und anderen Beobachtungen genügend zu thun sein. Der Raum für das Registrir-Observatorium wird im wesentlichen aus leeren Proviantkisten hergestellt werden; mit den Wohnräumen soll dieses Observatorium durch einen allseitig gedeckten Gang verbunden sein, um auch bei starken Schneeverwehungen noch sicher und bequem dorthin zu gelangen. Das absolute Observatorium wird im Winter aus einer Schneehütte bestehen. Im Sommer werde ich dazu ein festes Zelt benutzen, dessen Decke aus durchsichtiger weisser Seide besteht, wodurch ich genügendes Oberlicht für die Messungen erhalte. Während des Sommers gedenke ich dann eine Anzahl von Schlittenexpeditionen auszuführen, um einen möglichst grossen Theil des Gebiets rings um den magnetischen Pol zu vermessen. Ich will in diesem Sommer auch versuchen, mit dem Schiff einen Weg nach King William Insel zu finden, um im zweiten Sommer das Observatorium dorthin zu verlegen und nun von dort aus neue kleinere Expeditionen auszuführen. Im dritten Sommer

Digitized by Google

also 1906 will ich dann versuchen, in der Gegend der Herschel Insel meine Basis-Station zu errichten. Dort hoffe ich wohl Gelegenheit zu haben, mit McPherson—dem nördlichsten Fort der britischen Handels-Compagnie—in Verbindung zu treten. Hier sollen dann die Messungen ganz ebenso wie in den Jahren vorher fortgesetzt werden. Nach Ablauf der Zeit, welche ich mir gesetzt habe, werde ich dann die Rückreise um Alaska herum antreten und womöglich in Sitka Anschlussmessungen am magnetischen Observatorium der Vereinigten Staaten "Coast and Geodetic Survey" machen.

Ich schliesse meine Mittheilung, indem ich der Gesellschaft nochmals meinen Dank für die freundliche Einladung ausspreche.

Digitized by Google

MEAN VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES.

COMPILED BY D. L. HAZARD.[1]

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. Units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Pawlowsk	59 41 N	30 29 E	1898	0 30 ·3 E	70 39 ·7 N	·16522	·47077
			1899	0 34 ·1 E	70 38 ·8 N	·16536	·47078
Sitka[2]	57 03 N	135 20 W	1902	29 50 ·0 E	74 48 ·3 N	·15410	——
Katharinenburg	56 49 N	60 38 E	1898	9 55 ·6 E	70 40 ·2 N	·17802	·50752
			1899	9 59 ·6 E	70 39 ·7 N	·17795	·50706
Kasan	55 47 N	49 08 E	1894	7 39 ·7 E	68 37 ·5 N	·18572	·47451
			1895	7 43 ·8 E	68 35 ·5 N	·18580	·47390
			1896	7 47 ·1 E	68 33 ·7 N	.18605	·47381
			1897	7 54 ·8 E	68 34 ·8 N	·18616	·47454
Copenhagen	55 41 N	12 34 E	1899	10 15 ·8 W	68 40 ·0 N	·17490	·4478
			1899	18 17 ·7 W	68 51 ·8 N	·17273	·44677
Stonyhurst	53 51 N	2 28 W	1900	18 10 ·9 W	68 50 ·3 N	·17312	·44720
			1901	18 09 ·7 W	68 45 ·7 N	·17348	·44638
Hamburg	53 34 N	10 03 E	1896	11 36 ·7 W	67 38 ·8 N	·18061	·43921
Wilhelmshaven	53 32 N	8 09 E	1899	12 31 ·9 W	67 45 ·0 N	·18072	·44173
Potsdam	52 23 N	13 04 E	1899	10 00 ·7 W	66 33 ·3 N	·18818	·43392
			1900	9 56 ·3 W	66 33 ·7 N	·18844	·43466
Irkutsk	52 16 N	104 16 E	1898	2 02 ·6 E	70 13 ·2 N	·20137	·55991
			1899	2 01 ·5 E	70 13 ·7 N	·20133	·56009
de Bilt (Utrecht)	52 05 N	5 11 E	1898	13 59 ·1 W	——	·18487	——
			1899	13 54 ·7 W	——	·18502	——
Cahirciveen[3]	51 56 N	10 15 W	1899	21 35 ·0 W	68 33 ·0 N	·17739	·45164
			1900	21 30 ·0 W	68 29 ·6 N	·17765	·45082
			1901	21 27 ·7 W	68 26 ·3 N	·17801	·45048
Kew	51 28 N	0 19 W	1900	16 52 ·7 W	67 11 ·8 N	·18428	·43831
Greenwich	51 28 N	0 00	1899	16 34 ·2 W	67 10 ·2 N	·18419	·43754
			1900	16 29 ·0 W	67 08 .5 N	·18450	·43764
Uccle (Brussels)	50 48 N	4 21 E	1899	14 18 ·3 W	66 13 ·2 N	·18938	·42978
			1900	14 13 ·6 W	66 09 ·8 N	·18952	·42896
Falmouth	50 09 N	5 05 W	1899	18 32 ·7 W	66 48 ·7 N	·18663	·43569
			1900	18 29 ·1 W	66 45 ·2 N	·18689	·43507
Prague	50 05 N	14 25 E	1899	9 11 ·9 W	——	·19926	——
			1900	9 07 ·0 W	——	·19947	——
			1901	9 01 ·7 W	——	·19965	——
St.Helier(Jersey)	49 12 N	2 05 W	1900	16 59 ·7 W	65 45 ·5 N	——	——
			1901	16 56 ·5 W	65 42 ·7 N	——	——
Parc St. Maur	48 49 N	2 29 E	1898	14 53 ·8 W	64 58 ·3 N	·19676	·42140
			1899	14 49 ·5 W	64 55 ·7 N	·19704	·42119
Vienna	48 15 N	16 21 E	1898	8 24 ·1 W	——	·20797	——
O'Gyalla (Pesth)	47 53 N	18 12 E	1900	7 28 ·8 W	——	·21153	——
Odessa[4]	46 26 N	30 46 E	1898	4 41 ·5 W	62 30 ·5 N	·22033	·42341
			1899	4 36 ·7 W	62 18 ·9 N	·21869	·41660
			1900	4 29 ·9 W	62 18 ·0 N	·21876	·41659

[1] Use was made in this compilation of Dr. Chree's, table in *Proc. Roy Soc.* for 1901.

[2] Absolute observations January to June; preliminary results.

[3] Absolute observations only.

[4] There was evidently a change in the dip instrument between 1898 and 1899.

Digitized by Google

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. Units) Hor'l	Vert'l
Pola	44 52 N	15 51 E	1899	9 25 ·7 W	60 21 ·6 N	·22135	·38900
			1900	9 25 ·3 W	60 15 ·9 N	·22202	·38871
			1901	9 20 ·1 W	60 13 ·2 N	·22230	·38848
Nice	43 43 N	7 16 E	1899	12 04 ·0 W	60 11 ·7 N	·22390	·39087
Toronto	43 40 N	79 30 W	1897	4 53 ·0 W	———	·16650	———
Perpignan [1]	42 42 N	2 53 E	1897	13 51 ·3 W	60 03 ·5 N	.22440	·38959
			1898	13 47 ·0 W	60 01 ·7 N	·22386	·38818
			1899	13 42 ·5 W	60 00 ·0 N	·22418	·38829
Tiflis	41 43 N	44 48 E	1897	1 59 ·0 E	55 48 ·3 N	·25664	·37770
			1898	2 05 ·5 E	55 50 ·6 N	·25635	·37784
Capodimonte (Naples)	40 52 N	14 15 E	1898	9 22 ·6 W	———	———	———
			1899	9 15 ·8 W	———	———	———
			1900	9 10 ·2 W	———	———	———
Madrid	40 25 N	3 40 W	1898	15 51 ·3 W	———	———	———
			1899	15 48 ·4 W	———	———	———
Coimbra	40 12 N	8 25 W	1899	17 24 ·2 W	59 28 ·9 N	·22724	·38549
Baldwin [2]	38 47 N	95 10 W	1901	8 23 ·0 W	68 34 ·7 N	·21955	———
Cheltenham [3]	38 44 N	76 50 W	1902	5 06 .0 W	70 22 ·6 N	·20194	———
Lisbon	38 43 N	9 09 W	1900	17 18 ·0 W	57 54 ·8 W	·23516	·37484
Tokio	35 41 N	139 45 E	1897	4 29 ·9 W	49 02 ·8 W	·29816	·34356
Zi-ka-wei	31 12 N	121 26 E	1897	2 18 ·5 W	45 53 ·0 N	·32799	·33827
			1898	2 19 0 W	45 48 ·7 N	·32778	·33720
Havana	23 08 N	82 25 W	1898	3 10 ·8 E	52 30 ·7 N	·31166	·40634
Hong Kong	22 18 N	114 10 E	1899	0 21 ·1 E	31 29 ·4 N	·36676	·22465
Honolulu [4]	21 19 N	158 04 W	1902	9 17 ·4 E	40 14 ·7 N	·29245	———
Tacubaya	19 24 N	99 12 E	1895	7 45 ·6 E	44 22 ·2 N	·33428	·32764
Colaba (Bombay)	18 54 N	72 49 E	1897	0 32 ·5 E	20 59 ·1 N	·37449	·14364
			1898	0 29 ·7 E	21 05 ·8 N	·37435	·14448
			1899	0 26 ·5 E	21 13 ·9 N	·37437	·14540
Manila	14 35 N	120 58 E	1898	0 51 ·4 E	16 28 ·7 N	·37952	·11228
			1899	0 51 ·9 E	16 19 ·9 N	·37981	·11130
			1900	0 52 ·1 E	16 15 ·9 N	·38029	·11095
Batavia	6 11 S	106 49 E	1898	1 14 ·9 E	29 47 ·4 S	·36752	·21040
Dar-es-salem [5]	6 49 S	39 18 E	1896	8 41 ·6 W	36 50 ·8 S	·29004	·21735
			1897	8 29 ·9 W	36 53 ·3 S	·29009	·21771
			1898	8 18 ·1 W	36 56 ·8 S	·28966	·21785
Mauritius	20 06 S	57 33 E	1898	9 39 ·2 W	54 22 ·4 S	·23873	·33314
			1899	9 32 ·9 W	54 16 ·8 S	·23854	·33171
Rio de Janeiro [6]	22 55 S	43 11 W	1899	7 47 ·4 W	13 15 ·3 S	·2503	·0590
			1900	7 55 ·7 W	13 17 ·1 S	·2504	·0592
			1901	8 10 ·0 W	13 22 ·8 S	·2500	·0595
Melbourne	37 50 S	144 58 E	1898	8 20 ·1 E	67 22 ·4 S	·23364	·56050

[1] Intensity results at Perpignan prior to 1898 require the following corrections in order to reduce to the same standard as later results: Horizontal intensity,—.00088; vertical intensity,—.00153.

[2] Preliminary results from absolute observations.

[3] Absolute observations January to June; preliminary results.

[4] Data for 1896 and 1897 are from absolute observations only. For 1898 use was made of available magnetograph records.

[5] Absolute observations only.

Digitized by Google

THE CHRISTCHURCH MAGNETIC OBSERVATORY, NEW ZEALAND.

By C. Coleridge Farr, D. Sc.

The Observatory is situated in the Christchurch Botanical Gardens, in latitude 43° 31′ 50″ S.; longitude 172° 37′ 18″ E. The time employed in New Zealand is that of longitude 172° 30′ 00″ E., or 11^h 30^m E., and when Greenwich time is not stated as being adopted, it is this local standard time which is used at the observatory.

FIGURE 1. CHRISTCHURCH MAGNETIC OBSERVATORY; ABSOLUTE HOUSE.

The observatory consists of three buildings, situated sufficiently far from one another for the operations carried on in one to be without appreciable effect in the others. The "absolute house" and "variation house" are both constructed of material which has been tested and found free from magnetic effect. The absolute house is built of wood fastened with copper nails and brass screws; the roofing is of slate.

The superstructure of the variation house is similar in construction, whilst underneath the visible portion is a cellar in which the instruments (magnetograph, of the Kew pattern) are placed. The cellar was designed to maintain as uniform a temperature as possible, and the scheme has been very successful. The walls, built of concrete tested, are double, the outer one being one foot in thickness, and the inner nine inches thick, whilst between the two there is an air space all around three inches thick. The diurnal change of temperature is usually scarcely visible, though under exceptional circumstances the temperature may rise or fall a degree (Fahr.) in the twenty-four hours. The annual range of temperature is about 14° Fahr. The magnetograph work has been in progress since November, 1901.

Digitized by Google

FIGURE 2. CHRISTCHURCH MAGNETIC OBSERVATORY; VARIATION HOUSE.
[Magnetographs in cellar below.]

Besides the magnetic work, a Milne seismograph is installed and observations of atmospheric potential and the dissipation of electric changes are also made. There is also a set of meteorological instruments. The observatory is the base station of the British National Antarctic Expedition, and also of the Magnetic Survey of the Colony of New Zealand.

FIGURE 3. CHRISTCHURCH MAGNETIC OBSERVATORY; OFFICES AND SEISMOGRAPH CELLAR.

Digitized by Google

THE MAGNETIC OBSERVATORIES OF THE UNITED STATES COAST AND GEODETIC SURVEY IN OPERATION ON JULY 1, 1902.

By L. A. Bauer and J. A. Fleming.

I. SELECTION OF SITES OF THE MAGNETIC OBSERVATORIES.

[Abstract].[1]

The United States Coast and Geodetic Survey has in operation, in conformity with the plan of the magnetic survey of the United States and countries under its jurisdiction, outlined in Appendix 10, Report of the Superintendent of the Coast and Geodetic Survey for 1899,[2] four magnetic observatories at which the manifold variations of the Earth's magnetism are being continuously recorded by photographic means. These continuous records, besides serving other useful purposes, are utilized in referring the values of the magnetic elements, obtained at various stations and at various times by the field parties engaged in the magnetic survey, to a common time.

These four magnetic observatories, which constitute at present the primary magnetic base stations of the magnetic survey of the United States and countries under its jurisdiction, are as follows:

1. *The Cheltenham Magnetic Observatory*, situated at Cheltenham, Md., fourteen miles, or twenty-two and one-half kilometers, in an air line southeast from the United States Capitol at Washington City. This is the principal or standard magnetic observatory, where, in addition to the regular observatory work, all magnetic instruments are standardized;

2. *The Sitka Magnetic Observatory*, located at Sitka, Alaska, near the new Russian cemetery. The magnetic and meteorological observatory, which the Russians had in operation between 1842 and 1867, was situated on Japonski Island, in Sitka Harbor, about three-eighths of a mile, or three-fifths of a kilometer, west of the present site;

3. *The Honolulu Magnetic Observatory*, located on an immense coral plain twelve and one-half miles, or twenty kilometers, in an air line, west of the city of Honolulu, Hawaii;

4. *The Baldwin Magnetic Observatory*, situated at Baldwin, Kas., thirteen miles, or twenty-one kilometers, in an air line, south of Lawrence, Kansas. This observatory is a temporary one, and the magnetograph was mounted in an existing structure. The site for a more permanent observatory in the Western States has not yet been chosen.

In addition to the above, the Survey is contemplating, in the near future, the erection of a magnetic observatory in Porto Rico,[3] a region

[1] Abstracted from Appendix No. 5, Report of the Superintendent of the United States Coast and Geodetic Survey for 1902.

[2] Also to be found in this Journal, Vol. III, pp. 93-104.

[3] A set of self-registering instruments (declination and horizontal intensity) was mounted temporarily in Fort Isabel, Vieques Island, east of Porto Rico, and put in operation in February, 1903.

Digitized by Google

recommended as a desirable one for a magnetic observatory by the International Magnetic Conference held at Bristol, England, in 1898, and one which the recent volcanic eruptions in Martinique and concomitant magnetic storms have made doubly interesting and important for magnetic investigation. As soon as the magnetic survey of the extreme Western States is undertaken, the establishment of a magnetic observatory in that region will be imperative.

The selection of a suitable site for a magnetic observatory to be continuously and uninterruptedly in operation for a period of fifteen years, at least, is a most difficult matter in view of the rapid spread and development of electric car lines and electric power and lighting establishments. Nearly every prominent magnetic observatory over the entire globe has suffered more or less in recent years from stray industrial electric currents.

The disastrous effects from uninsulated electric car systems were first experienced in the United States, in 1892, at the Coast and Geodetic Survey magnetic observatory situated at San Antonio, Tex. When the facts were made known to prominent magneticians, some of them would not admit that the disturbances were due to stray currents from the San Antonio electric car line. To-day there is no longer any question that effects from such sources may be obtained five miles distant from the car lines.

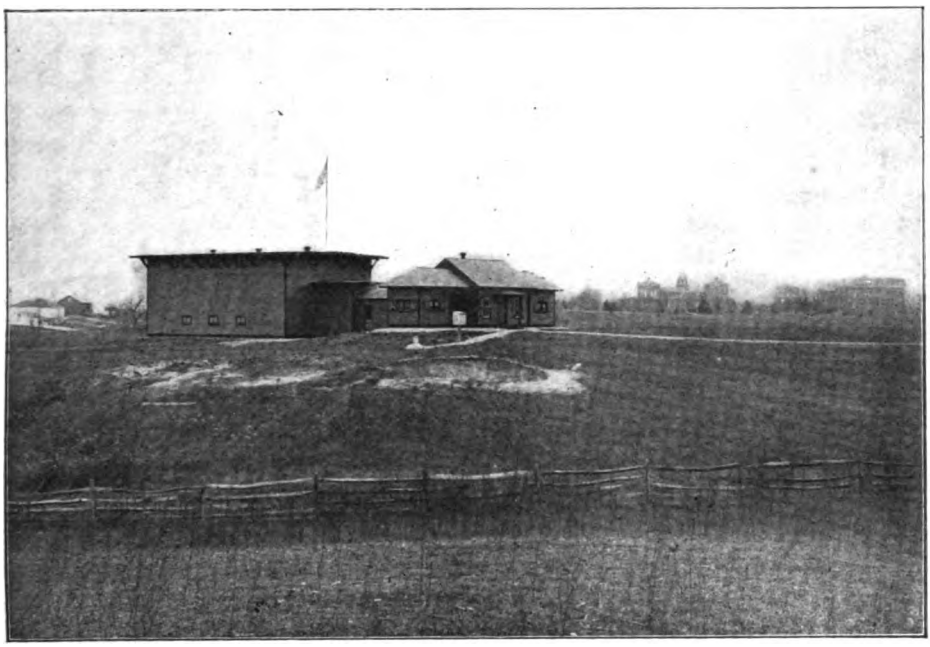
Having these experiences in mind, special care was taken in the selection of the sites for the new magnetic observatories of the Coast and Geodetic Survey. The idea was abandoned altogether that it would be possible to maintain an observatory for several years in any locality already well settled or possessing inducements for settlement in the near future.

The next point of prime consideration is the uniformity in the distribution of magnetism within the area to be occupied for the various kinds of work at a magnetic observatory, so as to avoid the necessity of a reduction of the magnetic elements to a normal station, and thereby to eliminate the necessity of controlling the constancy of the reduction—following a rule that pertains especially to magnetic work, viz., to avoid, *ab initio*, any cause for correction.

Further points to be considered apply to accessibility of the station, to freedom from other disturbing influences than those from electrical sources, to facilities obtainable in the locality for carrying out the observatory work, such as supplies and abundance of pure water for the photographic work, comfort and convenience of observers, mail and telegraphic communications, etc. If other than magnetic work is to be carried on, such as investigations in atmospheric and telluric electricity, seismology, and meteorology, full consideration must likewise be given to the demands of these special branches.

Digitized by Google

The sites for the first three observatories were selected after a careful personal examination of the regions by L. A. Bauer, that at Cheltenham in the spring and summer of 1899 and those at Sitka and Honolulu in the fall of 1900. Furthermore, as an additional precaution, J. A. Fleming was instructed that the selected sites were to be given another careful examination before the erection of the Sitka and Honolulu Observatories. In both instances the choice of the original location was confirmed. The site of the provisional magnetic observatory at Baldwin, Kansas, was se-



CHELTENHAM MAGNETIC OBSERVATORY (LOOKING NORTHEAST).

lected by W. C. Bauer and C. K. Edmunds. The four sites have thus far proven satisfactory.

THE SITE OF THE CHELTENHAM MAGNETIC OBSERVATORY.

A number of sites within a radius of about twenty-five miles of Washington City, in Virginia and Maryland, were examined, and the distribution of the magnetic elements tested before the final location was decided upon. The problem of establishing a standard magnetic observatory, which is expected to have a life embracing the period necessary for the general magnetic survey of the United States, and which is to be within convenient reach of the office of the Coast and Geodetic Survey at Washington, required special care, and several months were accordingly spent

Digitized by Google

before a decision was reached. As far as uniformity in distribution of magnetism was concerned, the magnetic survey of Maryland by L. A. Bauer, under the auspices of the Maryland Geological Survey, had already indicated that the region to the southeast of Washington would probably furnish the best site in this respect, and the additional examinations resulted in the selection of that region.

An area examined toward the northwest of Washington, embracing the region about Gaithersburg, Md., where one of the international latitude stations is situated, exhibited such remarkable local disturbances, even within the small strip of land occupied by the latitude observatory, that it had to be rejected at once as the site of a normal magnetic observatory.

Suggestions regarding the selection of an island in the Chesapeake Bay received consideration, but this plan was abandoned in view of the possibility of disturbing influence from passing ocean steamers, and because of the difficulty of access at all times, and of transporting delicate instruments to such a place.

The site finally selected is on the grounds of the Maryland Reform School, about one mile and a quarter west of the railroad station at Cheltenham, reached from Washington or Baltimore via the Pennsylvania Railroad, changing cars at Bowie to the Pope Creek Railroad, a single-track branch of the Pennsylvania system. The traffic on this branch consists of two local passenger trains in the morning, one in each direction; two similar trains in the afternoon; and an occasional local freight train. The grounds of the reform school embrace about 800 acres, and are surrounded on all sides by farms of large extent. The site leased by the Coast and Geodetic Survey for an indefinite number of years comprises nearly six acres, and is situated on the highest land between the Potomac and Patuxent Rivers, the altitude being about 225 feet above sea level. Cheltenham consists principally of the buildings belonging to the reform school, about half a dozen frame cottages, two churches, and the railroad station.

As far as can be seen at present, there will be little inducement to run electric car lines into this region. From the site of the magnetic observatory an extensive view is obtained of the country round about, and the opportunities are favorable for the successful prosecution of all the work planned for this observatory.

THE SITE OF THE SITKA MAGNETIC OBSERVATORY.

After an inspection of various places in Southeastern Alaska, Sitka was decided upon as fulfilling most nearly the requirements above set forth. Owing to the rapid development of some of the Alaskan towns in recent years and the general prevalence of local magnetic disturbances, special care had to be exercised. Sitka has steamer communication with Seattle about once a week throughout the year.

Digitized by Google

The site used by the Russians from 1843 to 1867 on Japonski Island is no longer suitable, and is occupied as a naval station. Owing to the mountains immediately back of Sitka it was not possible to get far away from the town. After a careful examination of various sites at Sitka by L. A. Bauer and J. A. Fleming, the site on a Government reservation near the new Russian cemetery was adopted. This site has since been set apart for the use of the Coast and Geodetic Survey by special executive order of the President of the United States. The magnetic observations made at the various sites examined revealed a sufficiently uniform distribution prevailing about Sitka.

THE SITE OF THE HONOLULU MAGNETIC OBSERVATORY.

Owing to the volcanic origin of the Hawaiian Islands, the requirements of a uniform magnetic distribution presented special difficulties. About a dozen sites on the island of Oahu were inspected and tested, and, usually, pronounced local disturbances within small areas manifested themselves in one or more of the magnetic elements. Sites on the Island of Hawaii were also inspected. As the facilities of communication are best for the Island of Oahu, on which Honolulu is situated, this island received first consideration. Observations made by L. A. Bauer and J. A. Fleming at various points on the immense coral plain to the west of Honolulu and Pearl Harbor, while indicating small irregularities in magnetic distribution, served to mark out a site within which sufficient uniformity was secured.

It was necessary to locate the observatory beyond any possible influence likely to arise from the large works to be erected at Pearl Harbor by the United States Navy Department and to provide against the possibility of electric-car communications of Pearl Harbor with Honolulu; also the observatory had to be sufficiently removed from the existing and contemplated mills and power plants of the neighboring large sugar-cane plantation and of the adjacent sisal plantation. This necessitated putting the observatory over two and one-half miles from the nearest village, in the midst of the coral plain, where, because of the absence of sufficient amount of tillable soil, the danger of encroachments from the plantations is minimized. This coral plain is mainly used at present as a cattle ranch. The area of the site leased from the ranch company is 4.3 acres. The site is about two-thirds of a mile from the railroad station, Sisal, on the Oahu Railroad, a single-track narrow-gauge road, the station consisting of the house occupied by the manager of the sisal plantation. From this station communication is had direct with Honolulu, distant twelve and one-half miles in an air line and twenty miles by railroad.

THE SITE OF THE BALDWIN MAGNETIC OBSERVATORY.

This observatory, as already stated, was intended to be in operation for a brief period while the magnetic survey of the States in the vicinity

Digitized by Google

was in progress, and no special buildings were erected, but such as already existed were adapted for the work.

Baldwin is a small college town, the site of Baker University. This place, being surrounded on all sides by large farms and being centrally situated, offered a good place for a temporary observatory. Owing to the international magnetic work begun in January, 1902, and because of delay in completing the magnetic survey of the neighboring States on account of the difficulty experienced in obtaining new magnetic outfits promptly, it has been necessary to continue the observatory longer than was originally contemplated.

II. CONSTRUCTION OF THE MAGNETIC OBSERVATORIES.

No attempt at architectural display in the construction of the buildings was made. In view of the uncertain life of a magnetic observatory, they were designed simply to fulfill as adequately as possible the requirements of the work without going to any unnecessary expense.

The general design of the three observatories, Cheltenham, Sitka, and Honolulu, planned by J. A. Fleming under the direction of L. A. Bauer, is the result of a careful study of past and existing plans and methods. This study indicated that, after the selection of sites well removed from all present and probable future local magnetic disturbance, the chief requisites desirable were: First, the elimination in construction of all materials showing any magnetic properties, even in the case of the variation observatory; second, the arrangements for absolute and variation instruments to be such that the mutual interaction of the various instruments would be inappreciable; third, the buildings for measurement of absolute values to be such as to admit of a number of simultaneous determinations without danger of appreciable mutual interaction of magnets of the various instruments; fourth, the building for variation observations to be constructed so as to have as nearly a uniform temperature throughout the year as possible, without employing extensive means for heating or cooling the rooms; fifth, the variation observatories to have accommodations for at least two sets of instruments—one eye-reading and one self-registering set—and that they be of a size sufficient to meet all reasonable demands now and later.

CONSTRUCTION OF THE CHELTENHAM MAGNETIC OBSERVATORY.

As a result of the *first condition* imposed above, the two structures, variation observatory and absolute observatory, consisting of an office flanked by two wings for the absolute observations, were built entirely of wood, and copper nails were used exclusively except when wooden pins could be substituted in framing. The greatest difficulty was found in selecting non-magnetic material for foundations and piers, and ten samples of building stones were tested with the Adie magnetograph and all found more or less unsatisfactory. To overcome this difficulty, the

Digitized by Google

foundations were designed to be two and one-half feet deep of rubble work, surmounted by a grillage of eight by eight inch timbers, five pieces high.

Fortunately, at Cheltenham a marble was procurable practically free from magnetic properties. The foundations of the variation observatory and of the piers extending to floor line were constructed of marble rub-

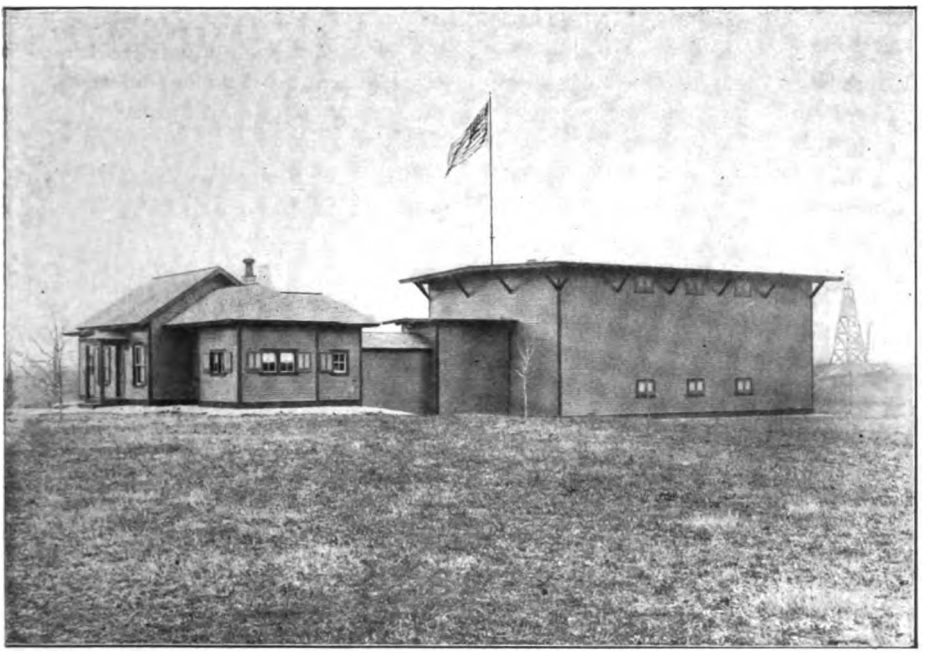


FIGURE 2. CHELTENHAM MAGNETIC OBSERVATORY (LOOKING NORTHWEST.)

ble work. Above the floor line some of the piers were built up to the desired height of cut marble pieces twelve and eight inches thick, the separate pieces being doweled together with three five-eighths inch copper dowels set in plaster of paris. Other piers put in later are of sandstone, carefully tested. The instrument supports in the west wing of the absolute observatory were made temporarily of cedar posts of suitable heights inclosed with tongue-and-groove casing and capped with hardwood blocks. In the east wing of the absolute observatory the instrument piers are of non-magnetic sandstone.

The chimney for the office, being fairly well removed from observation centers, was designed to be of a white brick which from tests was found to have a very small magnetic effect; a stone rubble construction would have been of inconveniently large section. For heating the office a wood stove of soapstone slabs was designed; this did not prove satis-

Digitized by Google

factory and was replaced by a copper-covered stove lined with fire brick. The question of hardware furnishings was also a source of difficulty, as nearly all of the so-called "brass" fittings were found to have iron parts which made it necessary to place special orders for the greater part of this material.

The *second condition* made it preferable that the buildings for absolute and variation observations should be separate and distinct, though questions of practical convenience required that they be as close together as possible without danger of appreciable magnetic interaction between the various instruments. Rough calculations of the mutual actions between a C. & G. S. magnetometer and the Adie instruments for varying intervening distances were made and the effect was found to be practically zero, for the instruments mounted forty feet apart, and the plans were made accordingly. The two buildings were connected by a covered wooden corrider.

In fulfilling the *third condition* the general plan already used by the Coast and Geodetic Survey at San Antonio, Texas, seemed best to follow. This consisted in erecting two buildings for absolute determinations, attaching the same as wings on either side of the office and connecting them by passageways. The doors from the office to these wings and also the rear door of the west wing of the absolute observatory have glass panels, so that communication by signal, or otherwise, from one wing to the other and to parties in tents outside can be conveniently and readily made. The east wing of the absolute observatory has a bay window extension on the north side to accommodate the Wild-Edelmann Observatory declinometer.

The *fourth condition* requires that either some sort of insulation be provided if the variation observatory be erected above ground, or that the general use of an underground construction be followed. The success in the matter of uniform temperature conditions attained at the Dutch Observatory at De Bilt, as well as the generally unsatisfactory conditions prevailing in most underground observatories because of moisture encountered in such structures, confirmed the opinion that a building above ground could be built so as to satisfy temperature conditions as well, or nearly so, as an underground structure, and would at the same time have the advantages of greater economy, convenience, and accessibility.

The choice of insulating packing for the walls was a question of prime consideration. The manufactured insulating materials on the market, on inquiry and examination, were found to contain more or less iron in their composition, and at the same time would have involved a much greater cost than permissible when used in such quantities as required. After a careful consideration of the non-magnetic materials available, carefully dried sawdust was decided upon as best adapted to the existing conditions.

Digitized by Google

In deciding upon the necessary thickness of insulating wall to reduce annual mean temperature range to within 4° C to 5° C, Fourier and Poisson's formula,

$$\log \frac{\Delta_0}{\Delta_p} = p \log e. \sqrt{\frac{\pi}{TK}} \qquad (1)$$

as found in Wild's article,[1] was adopted for a working basis. The significance of the various symbols is as follows: Δ_0 = external range of temperature in a time T expressed in minutes, Δ_p = range of temperature in the same time T in a room surrounded by a thickness of p cm.

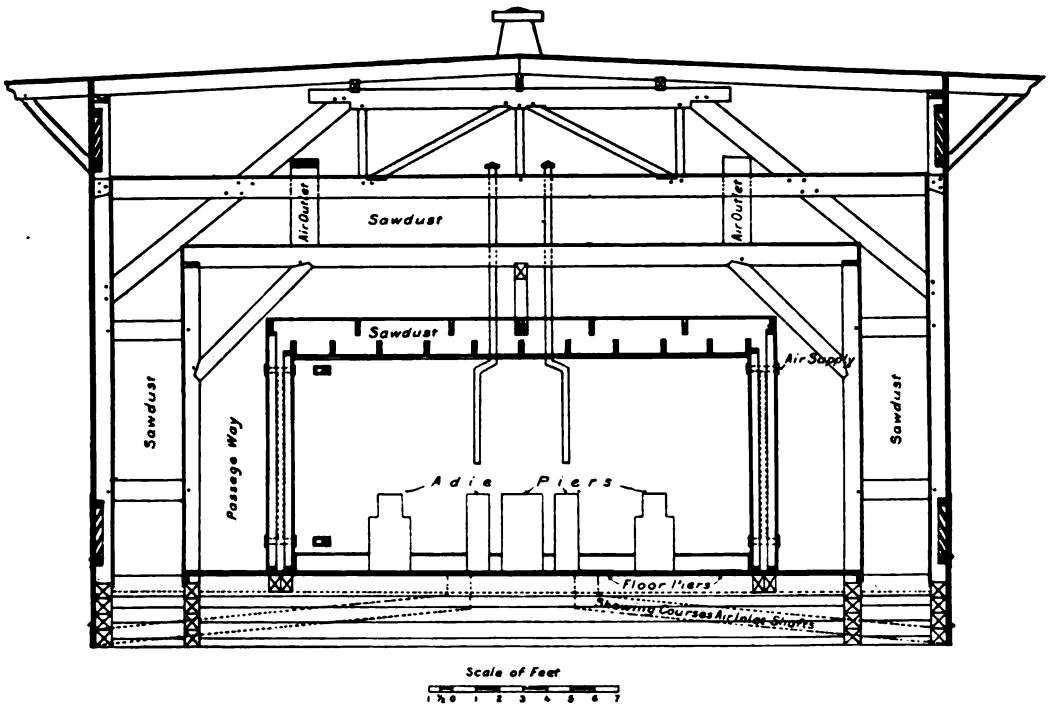


FIGURE 3. SECTION OF VARIATION OBSERVATORY, ADIE ROOM, CHELTENHAM MAGNETIC OBSERVATORY.

of insulting material, e = base of natural logarithms, and $K = \frac{k}{c}$ = what might be called the heat constant of the insulator, being a relation between its heat conductivity and its specific heat. According to Forbes, K for pine sawdust is 0.021, for pine across the grain 0.018, and for pine along the grain 0.053, whence it was assumed that for a wall packed with

[1] T. M., Vol. IV, p. 191.

Digitized by Google

sawdust, with such bracing and tying timbers as might be necessary. $K=0.035$. Reducing formula (1) with this value, we have for:

$$T=1 \text{ day}; \quad \log \Delta_p = \log \Delta_0 - 0.1084\, p. \tag{2}$$

$$T=1 \text{ year}; \quad \log \Delta_p = \log \Delta_0 - 0.0057\, p. \tag{3}$$

The mean daily range at Cheltenham was assumed to be 10° C., with a mean annual range of 25° C. Substitution of $\Delta_0=10°$ in (2) for values of p from 30 to 100 cm. indicated that under ideal conditions the interior mean daily range for such thicknesses of sawdust insulation would scarcely be an appreciable quantity. In determining upon a proper thickness to sufficiently reduce mean annual range, the curves were constructed from values of Δ_p derived by substitution in (3) of $p=30$, 40, 50— . . . 130 cm. with $\Delta_0=25°$, 20°, and 11° (the last two being the values of Δ_0 for Sitka and Honolulu respectively, as furnished by the United States Weather Bureau). Thus, for a wall with sawdust packing 4 feet thick, Δ_p for Washington, according to the curve, would be about 5°.1 without artificial heating or cooling, on the assumption of ideal conditions. Perfect conditions were, of course, practically impossible, but further insulation precautions were made, as noted hereafter, so as to bring about the best possible results.

The wall insulation of the variation observatory is as follows (see Figure No. 3): Beginning at outside of building, pine weatherboarding, 8-ply building paper, 1-inch pine sheathing, 8-inch air shaft, 1-inch pine sheathing, 8-ply paper, 3 feet pine sawdust, 8-ply paper, seven-eighths inch pine ceiling, 3 feet two inches air space of passageway, seven-eighths inch pine ceiling, 8-ply paper, 1 foot pine sawdust, 8-ply paper, seven-eighths inch pine ceiling. Slat ventilators or louvre windows are so arranged and provided with closely fitting shutters that during the winter the 8-inch air shaft referred to can be made practically air-tight, while during summer when opened these tend to admit of the passage and circulation of a cooling draft around building. The insulation beginning at the roof and going down is: Gravel and asphalt pitch roof, 1-inch pine sheathing, 3 feet 8 inches air space communicating with 8-inch air shaft around building, and provided with six louvre windows with close-fitting shutters as on those at the bottom of the air shaft, 1-inch rough pine floor, 3-foot filling of pine sawdust, 8-ply paper, seven-eighths inch pine ceiling, 3-foot air space above rooms, 1-inch rough pine floor, 1 foot 6 inches pine sawdust, 8-ply paper, seven-eighths inch ceiling. Insulation from bottom of foundation is 2 feet 8 inches of earth, 6-inch to 8-inch layer of screened gravel, about 3 feet pine sawdust, 1-inch pine under floor, 8-ply paper, seven-eighths inch pine tongue-and groove floor.

The greatest difficulty in obtaining the desired results lay in the necessity of providing openings through the walls for the ventilation of the rooms and for the means of ingress and egress. Four shafts, each

Digitized by Google

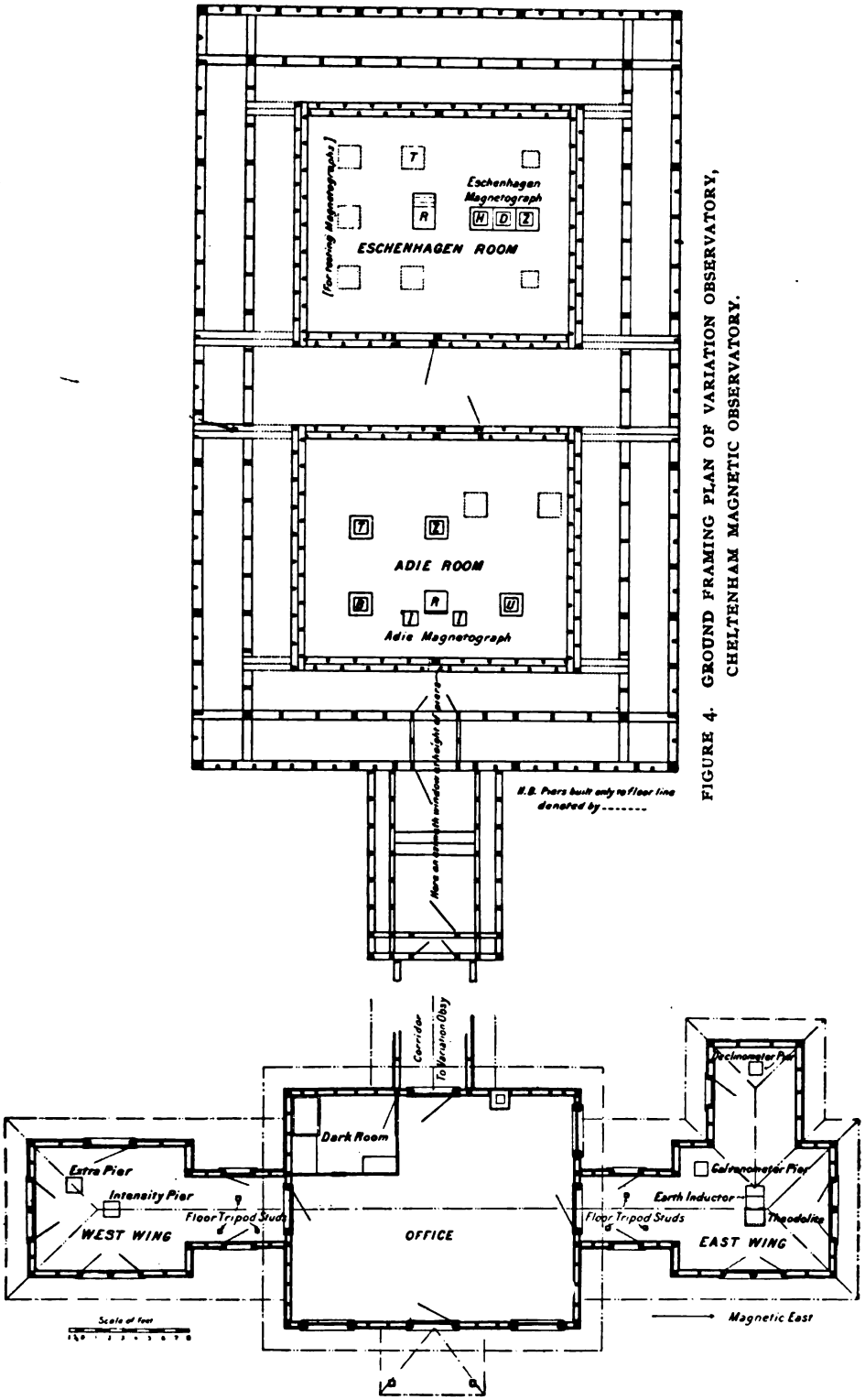


FIGURE 4. GROUND FRAMING PLAN OF VARIATION OBSERVATORY, CHELTENHAM MAGNETIC OBSERVATORY.

FIGURE 5. GROUND PLAN OF ABSOLUTE OBSERVATORY, CHELTENHAM MAGNETIC OBSERVATORY.

Digitized by Google

5 by 10 inches and about 16 feet long, furnish the air supply to the passageway, through wooden floor grates. These are provided with heavy rabbeted shutters made to fit very closely and fitted with refrigerator fasteners, so that they may be made air-tight. They are also provided at inlet with copper wire screens of double thickness to break force of wind blowing toward opening and to keep out such vermin as field mice. Ventilation of passageway is effected by four shafts opening into air space below the roof, each 6 by 10 inches and about 16 feet long, provided with close-fitting slides. Ventilation of air space below the roof is effected by three 14-inch copper "Star" ventilators. By the judicious use of these air ducts and ventilators, the danger of direct conduction of temperature changes through the shafts can be entirely eliminated. Ventilation of the magnetograph rooms from and into the passageway is effected in each room by four 3-inch square vertical shafts in the sawdust packing, having inlet or outlet just below the ceiling or above the baseboard, according to the arrangement of four closing slides provided for each. To carry off gases of combustion from the lamps of the magnetograph, 3-inch copper ventilators are provided.

Entrance into the building proper is had through a vestibule on the south side, as shown in Figures Nos. 1, 2 and 4, 10 feet by 13 feet 8 inches outside dimensions. The walls of the entrance are built like those of the main building, without the air shaft and with only two feet of sawdust packing. The outside door can be closed before opening a second door in a small entrance hall, which is 6 feet wide and 11 feet long; from this room a third door leads into an opening in the sawdust packing, whence a fourth door opens into the passageway around the rooms. In placing these doors, particular care was taken to make them close-fitting. Entrance into either of the magnetograph rooms is to be had only from the hall between the two rooms through 8-inch refrigerator-patterned doors packed with sawdust.

The diurnal range of the temperature was thus reduced at Cheltenham to a matter of a few tenths of a degree, and, in fact, it is believed that even this small variation will be eliminated as soon as some other source of light than the present lamps has been introduced. It has been repeatedly found that any sudden change of temperature which may amount to 50°–60° F. outside only makes itself felt gradually inside, and then does not amount to much over 0°.5, and may even be less than this amount. The annual range has been converted into a gradual progressive change, for which allowance can easily be made, and amounting to between one-half and one-third of what it would be outside.

The *fifth condition* imposed by the contemplated use of the Adie magnetograph as the eye-reading instrument and reserve magnetograph, made necessary two magnetograph rooms in the variation observatory, and that they be placed as far apart as economy of construction

Digitized by Google

would permit. The rooms are each 16 feet by 19 feet 6 inches, these dimensions giving ample space for the accommodation of the eye-reading Adie instruments in the south room, and for both the regular set of Eschenhagen self-registering instruments and a test set in the north room. The hallway between the two rooms is 5½ feet wide. (Figure No. 4.)

The outside dimensions of the variation observatory are 36 feet by 56 feet by 24 feet high, with entrance 10 feet by 13 feet. The outside dimensions of office are 18 feet by 22 feet, with two 5 feet by 7 feet passages leading to two wings for absolute observations, each 10 feet by 12 feet, thus making the total length of the absolute observatory, inclusive of the office, 60 feet. As already stated, the east wing of the absolute observatory has a bay-window extension of 6 by 7½ feet on the north side. (Figure No. 5.) The materials used were about 90 tons of building marble for foundations and piers, 85,000 feet of lumber, a trifle over one ton of copper nails, and something more than 190 tons of sawdust and shavings for insulation. No satisfactory bid from contractors for erecting the buildings having been received, the construction was placed in the hands of the designer, J. A. Fleming. The total cost of the buildings, including masonry and pier work, was something less than $6,900, which is $2,500 less than the lowest bid received. Some subsequent additions (piers, bay window, and covered corridor) have increased the cost about $500.

From Figure No. 4 it will be seen that provision was made, by the insertion of an azimuth door in the south wall of the Adie room of the variation observatory, for sighting from a point inside, through the corridor and office, on a distant azimuth mark whenever absolute observations are made inside the variation observatory. The arrangement of the absolute instruments is on a straight line passing east and west through the entire absolute building.

Construction of the Sitka Magnetic Observatory.

On account of the swampy condition of the ground at this observatory site, charred wooden posts, coated with tar and gravel and set in cement, were used instead of a stone-work foundation. The piers are similar in construction, and were provided with hardwood caps suitable to support the instruments. As a result of the prevailing moisture at Sitka it was necessary to replace these hardwood caps by marble slabs. The posts are inclosed above the floor line with tongue-and-groove casing.

A small frame dwelling house situated opposite the selected site was leased as an office building, and the absolute observatory, 10 by 12 feet in size, was placed in its proximity.

The general construction of the variation observatory is similar to that at Cheltenham, save that a pitched roof is provided, the greater

Digitized by Google

height so obtained offering a greater draft through the louvre windows at the sides.

The wall insulation was designed to secure the results desired at Cheltenham observatory, namely, a mean annual range of about 5° C. The insulation is as follows: Beginning at the outside of the building, pine weatherboarding, two thicknesses of 4-ply paper, 1-inch pine sheathing, 2-inch by 6-inch studding, forming air spaces connected by auger holes at bottom through studding, 1-inch sheathing, two thicknesses of 4-ply paper, 2 feet 4 inches of sawdust packing, two thicknesses

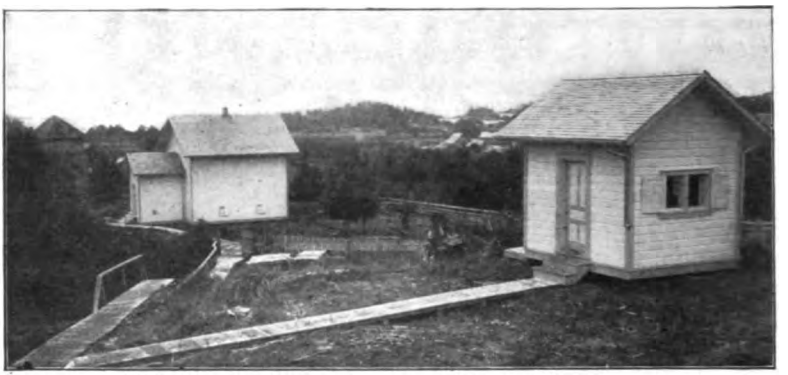


FIGURE 6. SITKA MAGNETIC OBSERVATORY, VARIATION AND ABSOLUTE BUILDINGS.

of 4-ply paper, seven-eighths inch pine ceiling, 2 feet 2 inches air space of passageway, save on west side, where it is 2 feet 10 inches, seven-eighths inch pine ceiling, two thicknesses of 4-ply paper, 11 inches of sawdust packing, two thicknesses of 4-ply paper, seven-eighths inch pine ceiling. Louvre windows with shutters, as at Cheltenham, are provided on the sides for the 6-inch air space. The insulation beginning at the roof and going down is: Shingle roof, attic air space, two thicknesses 4-ply paper, 1-inch rough pine floor, 2 feet 4 inches of sawdust, 1-inch rough pine floor, 2-inch air space, two thicknesses 4-ply paper, seven-eighths inch pine tongue-and-groove ceiling, 2 feet air space above magnetograph room, two thicknesses of 4-ply paper, 1-inch rough pine floor, 13 inches of sawdust, 1-inch rough pine floor, 2-inch air space, two thicknesses of 4-ply paper, seven-eighths inch ceiling. The insulation from bottom up is: One-inch rough pine floor, two thicknesses of 4-ply paper, 2 feet 6 inches of sawdust, 1-inch pine under floor, two thicknesses of 4-ply paper, seven-eighths inch tongue-andgroove floor.

The ventilation system is somewhat improved over that at Cheltenham in that the air supply is admitted first into the entrance vestibule by two 6-inch by 8-inch by 8-foot shafts in the walls, thence into the

Digitized by Google

passageway through two 5-inch by 8-inch shafts, instead of there being direct communication from the outside to the passageway. The supply of air to the magnetograph room is admitted from the passageway by three sets of ventilators. These consist of 4-inch square vertical shafts in the walls, with openings at the bottom and top, both into the inner room and into the passageway, the openings not being opposite each other, thus preventing entrance of light and dust. Ventilation of lamps from magnetograph room is effected by 3-inch zinc tubes to the attic space. Air communication from the passageway to the air space below the roof is effected by two horizontal square shafts, 8 by 8 inches, and about 6 feet long. Ventilation of the attic is effected by 20-inch copper ventilator.

As it was expected that both the eye-reading and self-recording instruments would be of the small Eschenhagen type, it was not necessary to provide two magnetograph rooms, as both sets could be accommodated, with the arrangements of piers shown in the plan, in one room 11½ by 14½ feet. The vestibule is 6 by 9½ feet, inside measure.

The outside dimensions of the variation observatory are: 24 by 27 feet, with an entrance 9½ by 12 feet. The absolute observatory is 10 by 12 feet. About 35,000 feet of lumber and 3,000 sacks of sawdust were used in the construction. The buildings were constructed under contract with James P. Jorgenson, of Juneau, Alaska, for $3,450. H. M. W. Edmonds, Magnetic Observer, Coast and Geodetic Survey, supervised the construction.

Construction of the Honolulu Magnetic Observatory.

Owing to the isolation of this station, an office with quarters for the observer had to be provided in addition to the two observatory buildings. On account of the excessive cost of building in the Hawaiian Islands the original plan to have this observatory similar to that at Sitka was abandoned and, in view of the more equable climatic conditions, the passageway was dispensed with, so that the instrument room is entered directly from the vestibule. The foundations and piers for both the absolute and the variation observatories are constructed of the coral rock which abounds in the immediate neighborhood which was found to be practically non-magnetic in character.

As the office had also to be used for living quarters where an uncertain amount of iron was likely to accumulate, it seemed best to remove it to some distance from the observatory. Owing to natural conditions of the site the distance between office and observatories is 450 feet.

As at Sitka, a pitched roof was provided. The air supply and outlet are also similar to those at Sitka with such exceptions as are necessary because of the omission of the passageway. The louvre windows to a 6-inch air space in the outer wall were made continuous around the bottom of the building, but were not provided with blinds because the

Digitized by Google

small annual range of temperature rendered them unnecessary. The upper louvre windows were omitted and a lower cornice board was used, thus allowing direct outside communiçatian to an air space under the roof made by covering the underside of the 6-inch rafters with heavy 3-ply building paper well battened on. An outlet from this 6-inch air shaft and the attic was made through an open ventilator, as shown by the illustrations. This arrangement was intended to accomplish the same result as the passageway, and was better adapted to the prevailing climatic conditions.

The wall insulation is based on the same principles as at other stations. The insulation is as follows: Beginning at the outside of the building, pine weatherboarding, 3-ply paper, 6-inch air space, 1-inch pine sheathing, 3-ply paper, 2 feet 2 inches of sawdust, 3-ply paper, seven-eighths inch tongue-and-groove ceiling. The insulation, beginning at the roof and going down, is: Shingle roof, 6-inch air space, 3-ply paper, attic air space,

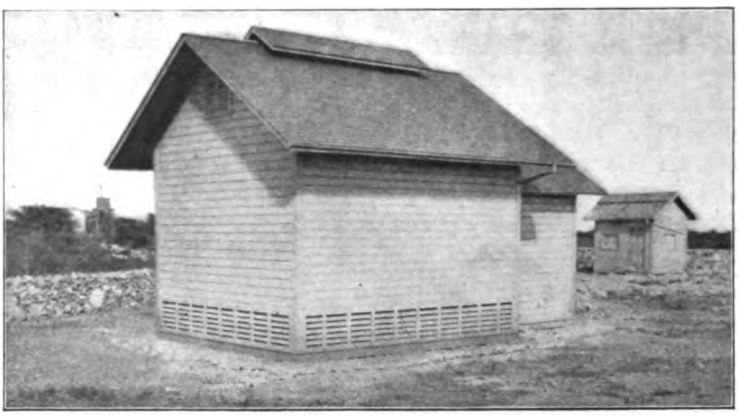


FIGURE 7. HONOLULU MAGNETIC OBSERVATORY.

3-ply paper, 2 feet of sawdust, 1-inch rough floor, 2-inch air space, 3-ply paper, seven-eighths inch tongue-and-groove ceiling. The insulation from the bottom up is: 3 to 4 inches of broken coral rock, 2 feet 2 inches of sawdust, 3-ply paper, seven-eighths inch tongue-and-grove floor.

As at Sitka, accommodations for two sets of instruments were provided in one room, 12½ by 14½ feet. The vestibule is 6 by 9½ feet, inside measure.

The outside dimensions of the variation observatory are 18 by 20 feet, with an entrance 9½ by 12 feet. The absolute observatory is 10 by 12 feet. The office is 12 by 16 feet, with a porch 6 by 12 feet, with a basement room for storage purposes, etc., 12 by 22 feet. The buildings were constructed under contract with Philip Savary, of Honolulu, H. I., for $2,450. The work of construction was supervised by the designer, J. A. Fleming, who also installed the instruments.

Digitized by Google

III. EQUIPMENT OF THE OBSERVATORIES.

CHELTENHAM MAGNETIC OBSERVATORY.

Variation instruments: Eschenhagen-Toepfer magnetograph as the principal photographic set and an Adie magnetograph formerly mounted at Los Angeles, Cal., from 1882 to 1889, and at San Antonio, Tex., from 1890 to 1895, this magnetograph having telescopes and scales for eye readings. It is the intention ultimately to use the Adie instrument simply for eye-reading observations, retaining, however, the photographic arrangement so that it can be put into function either to prevent loss of record, as for example, during adjustments of the Eschenhagen magnetograph or for the purpose of obtaining, in special investigations, a duplicate record with a totally different instrument. The plan of the Observatory (Figure 4) shows how the two magnetographs are mounted in separate rooms.

Absolute instruments: A large observatory Wild-Edelmann declinometer, earth inductor, and magnetometer, to determine, respectively, the declination, dip, and horizontal intensity, the instruments being always in place and ready for observations at any time. The declinometer, earth inductor, galvanometer, and large theodolite are mounted in the east wing of the absolute observatory (Figure 5), whereas the magnetometer for horizontal intensity observations (adapted also for secondary magnetic declination determinations with short magnet, when needed), is mounted in the west wing of the observatory (Figure 5). A set of field magnetic instruments also forms part of the outfit.

Accessories.—Atmospheric electricity instruments, meteorological instruments, two chronometers, thermographs, etc.

[In view of the fact that a Milne seismograph is now mounted at the Johns Hopkins University, Baltimore, about 40 miles from Cheltenham, the mounting of a seismograph at Cheltenham has been deferred temporarily. It is hoped soon to be able to install the necessary apparatus for earth-current observations, for which the Cheltenham site is admirably suited. It is the intention ultimately to carry out at this observatory all the work forming an essential part of a fully equipped, first-class magnetic observatory.]

SITKA MAGNETIC OBSERVATORY.

Variation Instruments.—Eschenhagen-Toepfer magnetograph, to be supplemented also with eye-reading instruments; the vertical intensity variometer is to be supplied by Schulze, of Potsdam.

Absolute Instruments.—Eschenhagen-Tesdorpf magnetometer, dip circle, and vertical force magnetometer; also, for field use, one Coast and Geodetic Survey magnetometer and an additional dip circle.

Accessories.—Meteorological instruments, two chronometers, thermographs, etc. This list is to be supplemented by a seismograph and atmospheric and telluric electricity instruments.

Digitized by Google

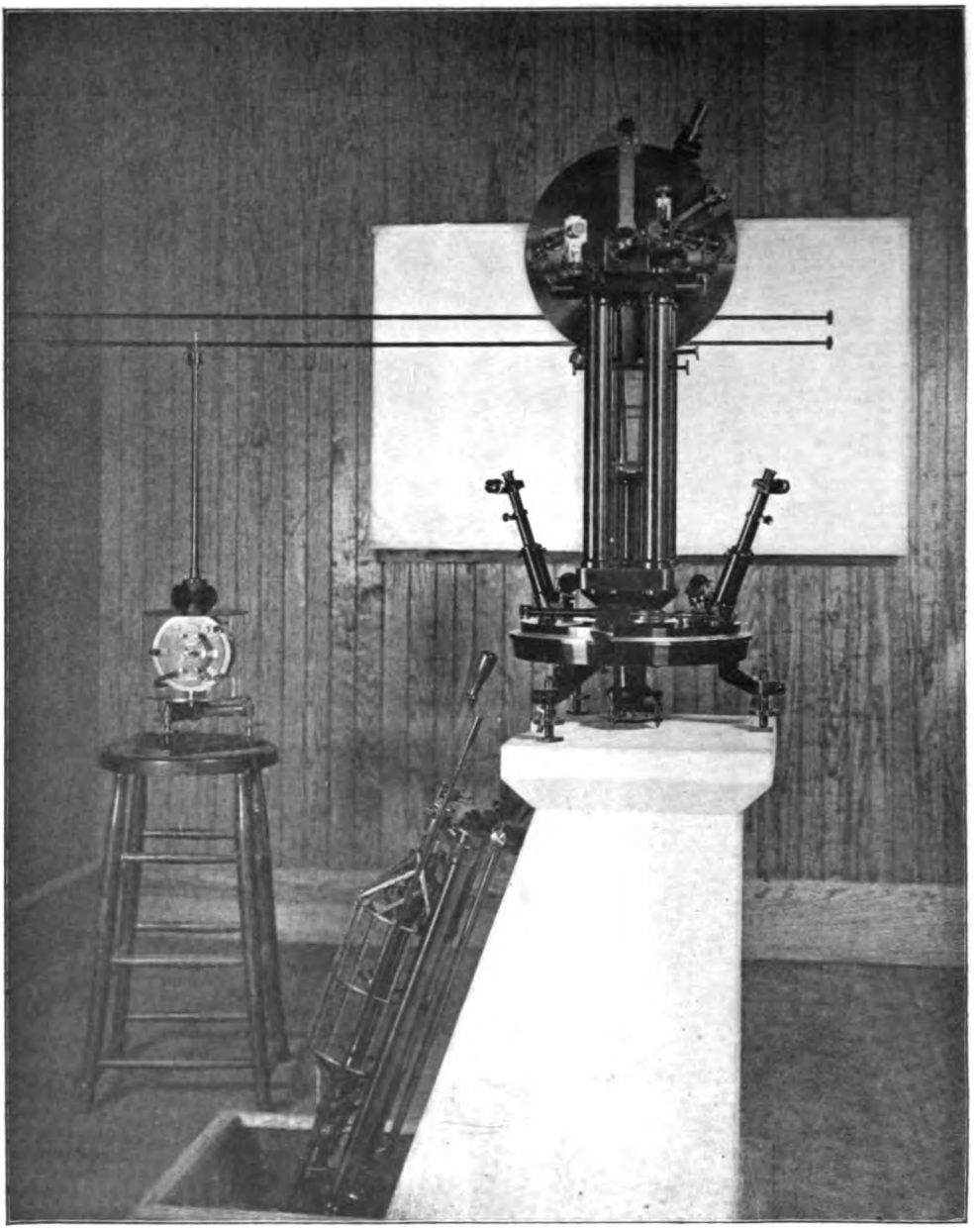


FIGURE 8. LARGE WILD-EDELMANN EARTH INDUCTOR, CHELTENHAM MAGNETIC OBSERVATORY.

Digitized by Google

Honolulu Magnetic Observatory.

Variation Instruments.—Eschenhagen-Toepfer magnetograph, to be supplemented by eye-reading instruments. The vertical intensity variometer is to be supplied by Schulze.

Absolute Instruments.—Wild-Edelmann field magnetometer, with earth inductor and galvanometer, and a complete set of magnetic instruments for field use.

Accessories.—Meteorological instruments, two chronometers, thermographs, etc., to be supplemented by atmospheric and telluric electricity instruments, and a seismograph.

Baldwin Magnetic Observatory.

Variation Instruments.—Eschenhagen-Toepfer magnetograph. The vertical intensity variometer is to be supplied by Schulze.

Absolute Instruments.—Cooke (India Magnetic Survey pattern) magnetometer and Casella dip circle. Also one set of field instruments.

Accessories.—Atmospheric electricity instruments, meteorological instruments, two chronometers and thermographs. This list to be supplemented by a seismograph.

The instruments and their mounting will be described in detail and illustrated in the publications of the results of the various observatories.

IV. GEOGRAPHIC POSITIONS OF AND MAGNETIC ELEMENTS AT THE MAGNETIC OBSERVATORIES.

Approximate magnetic Elements of the magnetic observatories for the period January–June, 1902.

Observatory.	Latitude north.	Longitude west of Greenwich.	Approximate altitude.		Declination.	Inclination.	Horizontal intensity in C.G.S. units.	Observer in charge July 1, 1902.
	° ′	° ′	*Feet.*	*Met.*	° ′	° ′		
Cheltenham	38 44.0	76 50.5	235	72	5 06 W	70 23	0.2019	L. G. Schultz.
Baldwin	38 47.0	95 10.0	1100	335	8 23 E	68 36	.2197	W. F. Wallis.
Sitka	57 02.9	135 20.2	50	15	29 50 E	74 48	.1541	H. M. W. Edmonds.
Honolulu	21 19.2	158 03.8	50	15	9 17 E	40 15	.2925	W. Weinrich, jr.

Digitized by Google

TROMHOLT'S CATALOGUE OF NORWEGIAN AURORAS.[1]

CLEVELAND ABBE.

No one has labored more faithfully to elucidate the problems of the aurora than Dr. Sophus Tromholt, of Rostock, Norway, who died April 17, 1896.

Among his most important works was that done when he, in 1882–3, personally occupied a station at Koutokeino in Finmark, Norway, in order to study the auroras observed by the Norwegian party at Bossekop, Norway, and the Finnish party at Sodan-Kyla. Tromholt was about sixty-six miles south of Bossekop and two hundred miles northeast of Sodan-Kyla, and observations of the auroras were made at all three stations at prearranged moments of time, for the express purpose of determining their altitudes. The results of these special observations have as yet been only partially published.

In Petermann's Mittheilungen, 1892, Vol. XXXVIII, Tromholt published a preliminary report on two important works that he then had in hand, namely, a complete catalogue of the observations of auroras, as recorded by Norwegian observers since the year 1594, with special descriptions of the more important auroral displays and a general analysis of the reports. As it seemed likely that there would be a long delay in the publication of this important work, the abstracts given by Tromholt in this preliminary communication were extremely welcome. My personal interest in the matter even led me to offer to supervise the publication in America of the original work, since the author had failed to find a publisher in Europe, but his early death closed our negotiations in this respect, and it appears that his manuscript was subsequently given, by his widow, to his friend J. Fr. Schroeter for the purpose of publication in Norway if possible. This desire has now been realized, and the publication at the joint expense of the Academy of Sciences at Christiania and the "Fridtjof Nansen Fund," as recommended by Prof. Dr. Mohn, is a valuable addition to our knowledge of the aurora borealis.

The volume is a quarto of 422 pages. Besides the preface by Schroeter, there is also a preface apparently about as prepared by Tromholt, from which we learn that he began the work of making this collection in 1879, and did not shrink from the great labor of examining general historical and archæological works, public and private libraries, and the archives of about a dozen public institutions, including the University Library at Leipsic. Especial attention was given to Norwegian

[1] Catalog der in Norwegen bis Juni 1878 beobachteten Nordlichter zusammengestellt von SOPHUS TROMHOLT.

Herausgegeben von J. FR. SCHROETER. Kristiania, 1902. Pp. XXIII+422. 24 x 31 cm.

Digitized by Google

newspapers, and in all cases the complete records of details were copied out. The dates are always reckoned, as in astronomy, from noon to noon; the four subdivisions of Norway are: I, north of 68° 30′; II, between 68° 30′ and 65°; III, between 65° and 61° 30′. The total number of stations from which observations have been gathered is 216, and the total number of sources of information referred to in the catalogue is about 300.

Under the editorship of Schroeter the material collected by Tromholt has been judiciously sifted, and apparently nothing has been published that is not a distinct addition to exact knowledge. Especially must we approve of Schroeter's good judgment as an editor in restricting the publication of detailed descriptions, partly because so many are given in the publications of the International Polar Research, 1882–3, by expert physicists, that nothing more would seem to be necessary; partly because there is abundant reason to think that the same aurora presents different aspects to observers a few miles apart, so that the mass of details must be useless until we understand more about the location and origin of the phenomena.

The list of auroras (Catalogue D) begins with September 27, 1594, and ends with April 22, 1878, covering 210 pages and giving about 9,000 observations on nearly 6,000 different auroral dates. For each date is given the age of the moon, the place and time of observation, a few words of description, and a reference to the source of information. In the second section, special descriptions are given of suspected auroras, from 1550 to 1569, and of auroras proper from 1739 to 1878. In the third section, Table A gives the monthly and annual sums of the days on which auroras were observed somewhere in Norway. The auroral year, like the snow year, is reckoned from July to June inclusive. The annual sums are then transformed into smoothed numbers by the formula $1/10\ (a+2b+4c+2d+e)$. The annual sums are also given for each of the four sections into which the author subdivides the area of Norway. On page 352 these annual sums, from 1761 to 1878, are combined in one total representing the monthly distribution of 5,891 days with auroras. This computation is given for each of the four subdivisions as well as for all Norway. The monthly sums are also converted into comparable percentages by reduction to a uniform summation of 1,000, whence it appears that in the northernmost division of Norway the annual periodicity shows a maximum at the winter solstice, whereas in the southernmost section two maxima occur corresponding to the equinoxes. Therefore, in the northern portion of Norway the annual periodicity is of the same character as in the Arctic regions generally. The southern division of Norway shows an annual period similar to that prevailing in middle latitudes. A combination of all the records of Tromholt in Norway and Rubenson in Sweden is given on

Digitized by Google

pages 353-414 for the years 1722, March 4, to 1878, April 22. The study of the geographical distribution of these observations shows again a maximum in January in the northern regions, and maxima about September 21st and March 21st in the southern regions.

In the third part of the volume Schroeter has presented us with a new and complete recomputation of the preliminary discussion found among the papers of Tromholt, so that the figures differ somewhat from those published by the latter in Petermann's Mittheilungen. Especially has he omitted the attempt to investigate the apparent periodicity of the aurora due to the observation by the varying brightness of the moon, since such an investigation can not lead to any satisfactory result, unless the cloudiness of the sky has been recorded uniformly throughout many lunar months. For the same reason, the study of the annual periodicity must be omitted. But we do not at first see why a similar argument would not hold good against the investigation of the sunspot period which Schroeter has undertaken. Notwithstanding the imperfections of his data, Schroeter concludes that the results for Norway are in general quite parallel to those deduced by Rubenson from observations in Sweden.

It is not likely that this great work of Tromholt's, taken in conjunction with its predecessors, exhausts all accessible European records, but it goes a long way towards preparing the way for a renewal of the comprehensive studies of the geographical and chronological distribution of auroras that were initiated by Fritz fifty years ago.

U. S. Weather Bureau

Dec. 18, 1900.

Digitized by Google

LORD KELVIN.

Sir William Thomson, the first Lord Kelvin, the son of James Thomson, LL. D., Professor of Mathematics at Glasgow, was born at Belfast, Ireland, June 26, 1824. He was a very precocious child, entered Glasgow University when only eleven years of age, matriculated at St. Peter's College, Cambridge, when seventeen, and the same year wrote a paper, entitled "Uniform Motion of Heat in Homogeneous Uniform Bodies," in which he defended the work of Fourier against some adverse criticism directed against it. The following year appeared his article on the "Linear Motion of Heat."

In 1845, at twenty-one years of age, he graduated from Cambridge as second wrangler and first Smith's prizeman; and was at once elected Fellow of St. Peter's College, which position he retained until his marriage in 1852; in 1872, under a new statute, he was elected to the Fellowship he now holds at St. Peter's. In 1845 also appeared "Elementary Laws of Static Electricity," in which he defended Coulomb's theory of the fundamental laws of electric attraction and repulsion against the attacks of Snow Harris and Faraday, and showed that the experiments of these men so far from being opposed to Coulomb's theory, were, when correctly interpreted, confirmatory of it.

He studied chemistry in Paris under Regnault. In 1846, he was elected to the chair of Natural Philosophy at Glasgow, to succeed Dr. Meikelham. From 1846–1851, he was editor of the Cambridge and Dublin Mathematical Journal, and about the same time he developed his theory of electrical images. In 1849 appeared his first paper on Thermodynamics. It was a critical account of Carnot's memoir of 1824, "Reflexions sur la Puissance Motrice du Feu," and embodied Joule's results on the "Mechanical Equivalent of Heat." It was this paper which first brought Carnot's work into prominent notice. At this time Kelvin believed in the caloric theory of heat. Shortly after this he showed how to define the absolute thermodynamic scale of temperature, and in 1852, in his paper on the "Secular Cooling of the Earth," he announced the principle of the "dissipation of energy."

In 1855 he delivered the Bakerian lecture on "Electrodynamics of Qualities of Metals," in which he called attention to what he called the "electric convection of heat." He now became interested in submarine telegraphy and devoted most of his time from 1857–1879 to this subject. He was electrician of the Atlantic cable of 1857–1865, of the French Atlantic cable, the Brazilian and River Platte, the West Indian, and the Mackay-Bennett Atlantic cables. During this period he invented several electrical instruments, the best known of which are the mirror galvanometer and the siphon recorder.

Digitized by Google

In 1867 appeared the first edition of his Natural Philosophy. He was President of the Edinburgh meeting of the British Association in 1871, President of the Royal Society in 1890–1895, three times President of the Royal Society of Edinburgh. He was knighted in 1866, and was created Baron Kelvin in 1892. In 1896 was celebrated the fiftieth anniversary of his accession to the chair of Natural Philosophy at Glasgow. He was twice married.

His work touches all departments of Physics; he calculated the size of atoms, determined the rigidity and age of the Earth, promulgated the vortex atom theory, devised a new form of mariner's compass, a navigational sounding machine, etc. He was much interested in navigation, and gave a method for correcting a compass for the magnetism of the ship, and published "Tables for Facilitating the Use of Sumner's Method at Sea." His original papers on mathematical and physical subjects have been reprinted in three series; viz., Electrostatics and Magnetism, 1 volume; Mathematical and Physical Papers, 3 volumes; Popular Lectures and Addresses, 3 volumes.

It is not possible to enumerate here all of the many honors showered upon him at home and abroad, nor to make specific mention of his contributions to the subjects of terrestrial magnetism and atmospheric electricity.

Helmholtz says of him: "His particular merit, in my opinion, consists in his treatment of mathematical physics. He has striven with great consistency to purify the mathematical theory from hypothetical assumptions which are not pure expressions of facts. In this way he has done very much to destroy the old unnatural separations between experimental and mathematical physics, and to reduce the latter to a precise and pure expression of the laws of phenomena. His electrical instruments and methods of observation, by which he has rendered, among other things, electrical phenomena as precisely measurable as magnetic or galvanic forces, gives the most striking illustration of how much can be gained for practical purposes by a close insight into theoretical questions; and his papers on thermodynamics and the experimental confirmation on several most surprising theoretical conclusions deduced from Carnot's axiom, point in the same direction."

An article in Nature, 1876, concludes with the words: "British science may be congratulated on the fact that in Sir William Thomson the most brilliant genius of the investigator is associated with the most lovable qualities of the man. His single-minded enthusiasm for the promotion of knowledge, his wealth of kindliness for younger men and fellow-workers, and his splendid modesty are among the qualities for which those who know him best admire him most."[1]

[1] The block from which the portrait of Lord Kelvin is reproduced was courteously furnished by the editors of the *Electrical World and Engineer*.—ED.

Digitized by Google

NOTES

1. *Zi-ka-wei Magnetic Observatory.* We regret to be informed that the usefulness of the observatory work is threatened by projected electric car lines within one-half mile.

2. *Meteorological reporter of India.* *Sir John Eliot, F. R. S.*, who has filled this office with great success for many years, will retire from office at the end of the present year. *Mr. Gilbert T. Walker*, M. A., Fellow of Trinity College, Cambridge, has been appointed assistant meteorological reporter and will proceed to India during the coming summer; it is understood that he will succeed Sir John Eliot upon his retirement. Mr. Walker was senior wrangler in the mathematical tripos in 1889, took the B. S. degree in November, 1890, at the University of London, and was shortly afterwards elected Fellow of Trinity. In 1895 he was appointed lecturer in mathematical physics at Trinity. He is the author of several well-known papers on the dynamics of the boomerang. His paper on "Aberration and Some Problems connected with the Electro-magnetic Field" was awarded the Adams Prize for 1899.

Mr. Walker recently visited the following United States scientific Institutions with a view of a study of methods: Weather Bureau, Coast and Geodetic Survey, and Cheltenham Magnetic Observatory, Blue Hill Observatory, and the Yerkes Observatory.

3. *Eschenhagen's Library.* We are informed that the widow of the late lamented Eschenhagen is prepared to dispose of her husband's library. A list of books can be obtained from Mr. E. Stück, assistant, Marine Observatorium, Wilhelmshaven, Germany.

4. *Major General C. J. B. Riddle, C. B., F. R. S.* We regret to announce the death, at the advanced age of eighty-six, of this distinguished pioneer in the advancement of the sciences of terrestrial magnetism and meteorology. His "Magnetical Instructions," in many respects, have as yet deen unsurpassed. It is hoped to publish a portrait of him in a future issue.

5. *List of Observatories.* The Smithsonian Institution has recently issued (Smithsonian Miscellaneous Collections 1259) a handy alphabetical list of observatories of every description. Opposite each entry is indicated, by suitable letters, the class or classes of work each institution is engaged in.

Digitized by Google

6. *Porto Rico Magnetic Observatory.* The United States Coast and Geodetic Survey established, under the direction of L. A. Bauer, a temporary magnetic observatory in Fort Isabel, on Vieques Island, to the east of Porto Rico. The instruments at present in operation since March 1st are, a magnetograph consisting of a Brooke unifilar and a bifilar magnetometer with Eschenhagen-Toepfer recording apparatus and a set of absolute instruments. This equipment will be supplemented by a vertical intensity variograph and a seismograph. The observatory is within two hundred and fifty miles of the Island of Martinique.

7. *Magnetic Survey of Prussia.* During 1901 Dr. Edler determined the magnetic elements at forty-four stations in the northwest part of Prussia and in 1902 at forty-nine stations in the west part. There remains the southwest portion and the repetition of observations at a certain number of repeat stations for the purpose of furnishing the necessary data for the reduction to a common epoch.

8. *Magnetically disturbed area in the Ries in Bavaria.* Prof. Haussmann investigated, in August of last year, the magnetic disturbances in this region at fifty-four stations. He hopes soon to be able to publish the results.

9. *Magnetic Survey of New Zealand.* Dr. Farr writes that the magnetic survey is making good progress. Mr. Skey attends to the field work.

10. *Professor Dr. von Neumayer.* It will certainly be a matter of regret to all readers of this JOURNAL to learn that the genial director of the Deutsche Seewarte has retired from the post which he has filled for so many years with such signal success. The title of "Excellence" has been awarded to him by the German Emperor.

Digitized by Google

ABSTRACTS AND REVIEWS

TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY AT THE INTERNATIONAL AERONAUTICAL CONGRESS, 1902.[1]

[Extract.]

The third meeting of the International Committee for Scientific Aeronautics appointed by the meteorologists in 1896 was held at Berlin May 20-24, 1902, the meeting having been well attended. The following extract is made from Mr. Rotch's summary of such matters pertaining to terrestrial magnetism and atmospheric electricity:

"The last session of the Congress was devoted to a discussion of measurements of atmospheric electricity and terrestrial magnetism in balloons. Assuming that the electrification of the air occurs through 'ions' or 'electrons,' as shown by the dispersion apparatus of Elster and Geitel, it is of great interest to determine how the constitution of the air, as regards positive and negative ions, varies with height. By using an aspirator to bring a definite quantity of air over the apparatus, Professor Ebert, of Munich, said that he had obtained absolute measurements of the quantity of free electricity in a cubic meter of air. In the discussion, Dr. von Bezold remarked that the connection between the Föhn wind and the number of ions in the air was now being studied. The air brought down from a great height by the Föhn carries more ions to a lower level, and there thus appeared to be a relation between mountain sickness and the well-known physiological effects of the Föhn. Professor Palazzo, of Rome, explained his photographic arrangement of Exner's electrometer, for use in balloons, and Dr. Linke, of Potsdam, described the measurements he had made in balloons to determine the change or potential and conductivity of the air. He had confirmed his early results that the potential was always positive, but found variation of the conductivity in cloud strata depends upon the weather conditions. The vertical motion of the balloon introduced complications which made the dispersion observations very difficult. On the request of Professor Ebert, the Congress recognized the importance of executing electrical measurements in balloons. The same speaker showed an apparatus for determining the horizontal magnetic intensity in a balloon without knowing either the astronomical or magnetic meridian. This is not only of scientific importance, but may be practically useful to guide the aeronaut at night and when he is in the clouds or over the sea. Dr. Marcuse, of Berlin, then showed an instrument for determining astronomically in a balloon its position. Dr. Kassner, of Berlin, suggested that kites and kite-balloons might be employed in the following scientific investigations: in physics for the determination of the conditions affecting the velocity of sound, in geodesy and astronomy for researches as to the causes

[1] Rotch, A. L. The International Aeronautical Congress, Repr. Science, Aug. 22, 1902, 6 pp.

Digitized by Google

of the variation in atmospheric rafraction and in meteorology for a study of the action of 'hail shooting.' Finally Director Archenhold, of the Treptow Observatory, in Berlin, said that the volcanic eruptions in the West Indies may produce optical phenomena similar to those following the Krakatoa explosion, namely, first brilliant sunsets and then the luminous night clouds which would be first perceived by aeronauts during nocturnal ascensions."

CHAUVEAU'S "RECHERCHES SUR L'ELECTRICITE ATMOSPHERIQUE."

Under this title Prof. A. B. Chauveau, of the Central Meteorological Bureau, Paris, has issued recently two memoirs giving a most interesting and comprehensive report of his study of atmospheric electricity. The first memoir is devoted to an historic and bibliographic introduction to the science. Chapter I describes the various phenomena and manifestations of atmospheric electricity; Chapter II gives a historical account of the developement of the science together with a description of the apparatus and methods used; Chapter III is devoted to a statement and discussion of the various theories relative to the origin of atmospheric electricity. The author strongly favors the theories of Sohncke in holding that atmospheric electricity has its origin in the friction between the air strata immediately above and below the isothermal of 0°, and of Lenard who ascribes its origin to the action of ocean waves. As for Edlund's theory, which ascribes it to an electric field created by the rotation of the earth, it is held to be inadmissible.

In the second memoir, Part First, Chapter I describes the Mascart photographic registering apparatus; Chapter II, the methods used in measuring high potentials; Chapter III the installation of apparatus in the Central Bureau and on the Eiffel Tower. Part Second, Chapter I, is devoted to a discussion of observations made near the earth's surface; Chapter II to a discussion of the observations made at the Central Bureau; Chapter III to observations made on the Eiffel Tower; Chapter IV takes up a discussion of special observations, and investigations of special phenomena; Chapter V is given to a discussion of the results obtained at the Central Bureau and on the Eiffel Tower, and to the enunciation of the general law of the daily variations. At the end of this memoir there are a number of beautiful cuts showing the various instruments used, and many excellent reproductions of photographic curves.

L. G. SCHULTZ.

OBSERVATIONS OF THE ELECTRIC CONDUCTIVITY OF THE ATMOSPHERE AT CAPE TOWN, SOUTH AFRICA.

[Abstract][1]

Observations of the electrical conductivity of the atmosphere were carried on from May 21 to August 25, 1902, at the South African College, Cape Town, by W. H. Logeman. The original Elster and Geitel apparatus, *with protecting cylinder*, was used throughout the work. The quantity of electricity dissipated during an interval of fifteen minutes was noted for both positive and negative charges, and two sets of readings were made on each day. During May and June the conductivity was somewhat greater during

[1] From MS. communication forwarded to the Editor.

Digitized by Google

the afternoon than during the morning: but during the morning slightly more of the positive charge was dissipated, while during the afternoon the amount of negative charge dissipated was slightly in excess. During July there was a marked difference between the morning and afternoon results, the conductivity being much greater during the afternoon; but for this month, more of the negative charge was dissipated during the morning and more of the positive during the afternoon. L. G. SCHULTZ.

ATMOSPHERIC ELECTRICITY OBSERVATIONS BY A. GOCKEL.[1]

This paper gives the results of atmospheric electrical observations made during the months of August and September, 1901, in Biscra, in the Oasis Tougourt, two hundred kilometers south of Biscra, at Hamman el Lif on the African coast, near Tunis; during March, 1902, at Zermatt and at odd times at Freiburg. The instrumental equipment consisted of an Exner electroscope, with a burning taper as a collector; Elster and Geitel's conductivity apparatus *without the protecting cylinder;* but in order to protect the apparatus against the earth's electrical field a wire cage was used; an Elster and Geitel actinometer for measu ring the ultraviolet rays; a Corva actinometer for measuring total solar radiation; a barometer and a hygrometer.

Strong winds and high temperatures interfered, to a great extent, with the observations at Biscra. The potentials were low and the values observed contradicted, in a measure, the results obtained during a previous investigation. At Tougourt sufficient data were not obtained to determine the daily period of potential variation, but they clearly show that afternoon gradients are generally higher than those of the forenoon. Here the dispersion coefficient was found to be remarkably low at sunset. While a decrease in the electrical conductivity of the air is an effect commonly observed, it is nowhere so marked as at Tougourt, and this fact accounts for the high potentials observed here during the late afternoon. No relation was discovered between the vapor pressure and the conductivity of the air; but observations at all places in the desert show that the time of minimum conductivity and maximum potential coincides with the times of minimum barometric pressure. At Hamman el Lif, on the sea shore, the conductivity was less and the potential was greater than on the desert.

During January, 1902, observations were carried out at Guggisburg in the Swiss Alps where the air is free from dust and other impurities which usually affect the electrical state at lower levels. On the two days on which observations were made, an anti-cyclonic area lay over the Central Switzerland and a Föhn wind prevailed at the place of observation. The relative humidity was low and both the conductivity and potentials were high. The formation of dense fog masses in the lower valleys and the Föhn coming from the upper air highly charged with ions caused these abnormal electrical conditions.

Observations on the Leysin Plateau, 1000 meters above the valley of the Rhone, show, nicely, the changes of the potential and conductivity of the air which occur in connection with well marked rain conditions. At Zermatt the observations show the electrical changes which accompany changes of pressure

[1] Luftelektrische Untersuchungen von ALBERT GOCKEL, Freiburg, (Schweig) 1902, Veröff. d. Un. Freiburg, Neue Folge, Fasc. IV, 56 pp., 1 pl., 17 x 25 cm.

Digitized by Google

in mountain regions; and, in addition to observations at other mountain stations, they also bring out in a remarkable manner the effect of solar radiation upon potential changes, and throw much light upon Exner's "spring maxima." No relation was found to exist between the relative humidity and electrical state of the air. Actinometric measurements show that the Sun's rays may affect the air potentials in three ways: 1. The ultraviolet rays may exert an inductive effect upon the negatively charged surface of the earth: or 2. These rays may increase the conductivity of the air; 3. Particles which affect the transparency of the air may possess a charge of their own.

Leaving out of consideration small disturbances, all the observations seem to show that the normal daily period of potential variation consists of a single oscillation with a daytime maximum and a nighttime minimum, at places free from the influence of objects on the earth's surface; but at places where this influence is strongly felt the daily period is a double one. Of all the meteorological elements, air currents, set up by changes in temperature, are the most effective agents in causing potential variations. L. G. SCHULTZ.

STUDIES IN ATMOSPHERIC ELECTRICITY BY Y. HOMMA.[1]

[Abstract.]

The atmospheric electricity records, made at the Central Meteorological Observatory of Japan, during the year 1897, are discussed in this paper. The observatory is far enough from the city of Tokyo to be free from the effect of dust and smoke. The equipment consisted of a water-dropper collector, the end of whose nozzle was 2m from the side of the building and 1.7m from the ground, and a Kelvin-Mascart self-registering electrometer.

A cursory inspection of the traces shows that the potential varied in a most irregular and capricious manner; that there was a decided tendency toward high potentials in the cold seasons; that the morning maximum occurred, uniformly, about an hour after sunrise throughout all seasons while the evening maximum occurred anywhere from 7.00 p. m. to midnight.

After stating the various theories of atmospheric electricity, placing special stress upon the friction theory of Sohncke, and the ion theory of J. J. Thomson, as developed by Elster and Geitel, the author expresses a strong leaning toward the friction theory of Sohncke and describes several experiments which go to show how objects may become electrified by friction. Leaves, twigs, wood, etc., were placed upon an insulator and a stream of fine sand was poured upon them from an insulated vessel. The sand became negatively and the other objects positively electrified. Leaves, twigs, wood, dry ice, etc., were placed upon an insulator and a jet of steam was made to play upon them. All objects on the insulator showed negative electrification except dry ice which was positively charged. Furthermore it was found that ice was positive against all substances which were tested. A piece of lighted candle was placed upon an insulator to serve as a collector. When a gas flame was brought near it the electrometer showed a negative electrification; a stream of unignited gas, however, showed no charge. The same effect was

[1] Journal of the Coll. of Science, Imper. Univ. Tokyo, Japan; Vol. XVI.

Digitized by Google

noted when a current of warm air was sent against the collector; but a positive charge was observed when a current of cold air was used. This experiment showed that when two masses of air, at different temperatures, are in contact the hotter one becomes positively and the cooler one negatively electrified. In order to verify this conclusion two adjoining rooms were brought to temperatures differing by about 10° and the collector was placed near the connecting door. When the door was slightly opened the flame was blown toward the warmer room and the electrometer showed an increase in potential.

The author agrees with Sohncke in holding that the layer of air just above the plane containing the isothermal of 0° and carrying ice spicules, becomes positively electrified by friction with the layer lying just below that plane and carrying water particles; and that the negative electricity of the latter partly passes down to Earth through precipitation. And, in addition, he believes that the contact of warm and cold air, the intensity of the wind and the amount of dust in the air are circumstances which play an important part in the phenomena of atmospheric electricity.

A study of the simultaneous meteorological records showed that strong winds, which raised dust, were accompanied by negative potentials; but when the ground was wet from previous precipitation the potentials remained positive although the wind blew violently. Mornings with fog or haze were generally characterized by high potentials showing energetic fluctuations.

Excessively high potentials were recorded on days with excessively low temperatures.

When rain was moderate, and the drops fine, the potential was low and positive, with only slight variations. When a violent downpour occurred the potentials became, at once, negative and showed irregular and energetic variations; as precipitation became less the potential went back to positive.

In the case of snowfall the variations were much more regular though no less energetic than with rainfall; and they seemed to show a quasiperiodic nature.

The author's conclusions are summarized as follows:

1. The negative potential observed during strong wind is entirely due to the negative electrification of the dust raised and carried in the atmosphere by friction with terrestrial objects.

2. Similarly the high potential observed during fog or haze is due to the positive electrification of the water particles composing it.

3. When a mass of cold air comes in contact with a mass of warm air, the former becomes positively electrified with respect to the latter. This fact is probably one of the causes which determine the normal distribution of the electric field in the atmosphere. Also it may account for the fact that an abnormally high potential is generally accompanied by an abnormally low temperature.

4. The invariably high potentials at or near sunrise are probably due to the fact that the air laying near the surface has then a temperature lower than that of the air above it, and becomes in consequence, positively electrified.

5. When two masses of air at different temperatures happen to be mixed suddenly, the electric field is violently disturbed. The disturbances are, however, just such as are in accord with the facts stated in 3.

L. G. SCHULTZ.

Digitized by Google

MAGNETIC OBSERVATIONS ABOUT LAKE BALATON, HUNGARY, IN 1901.[1]

This campaign, which had for its object the revealing of possible local disturbances in the vicinity of Lake Balaton, was conducted under the auspices of the Balaton Committee of the Royal Hungarian Geographical Society, and embraced fifteen stations, at which the three elements were observed. The following instruments were used: Lamont pattern magnetometer[2] for declination and horizontal intensity, a Dover dip circle,[2] a theodolite—reading to 5″ and by estimation to 1″—by Starke for time and azimuth, two pocket chronometers by Vorauer and Courvoisier, and observing tent. Great care was exercised in the selection of stations to avoid artificial local disturbances. The method of observation and reduction was that used by I. Kurländer in the survey of Hungary, the reduction to common epoch of August 1, 1901, being made by means of the magnetograms at the Pola Observatory. The descriptions of the stations are in general not sufficiently explicit; the station Versprém is practically the same as occupied by Kurländer in 1892; without further information the impression is aroused that this station may be too close to a building.

From the remarks on the astronomical observations it is not clear why, with the instrument used, it was necessary, sighting on the sun, to make the time observations apart from the azimuth observations, and why the alt-azimuth method of observation and reduction was not at once used. The mean error of the azimuth observation would appear in general to be less than $\pm$ 0′.4, the greater part of which is due to the error of pointings on the mark before and after the solar observations, produced by the twist in the tripod by the Sun beating on it. This mean error seems to be deduced, however, simply from the separate pointings on the Sun made at practically the same hour angle, and, hence, does not include the errors, which would be revealed by observations at various hour angles, especially by A. M. and P. M. observations.

Comparisons of the magnetometer with a similar one loaned by the Vienna Meteorological and Magnetic Observatory, showed connection to Vienna standard to be — 55 γ before and — 52 γ after the trip, indicating a constant condition of instrument throughout. Summaries of intensity, declination, and dip follow. The observer does not feel that the best results were obtained with the dip circle, and in conformity with usual experience found the results especially unsatisfactory in moist conditions. After a general summary of results the author discusses a magnetic anomaly at Veszprém, his observations being confirmed by those of Kurländer. An anomaly of less prominence is also noted at Balaton-Beréney. Following a table of the X, Y, and Z components are six sketch maps showing isodynamics of horizontal intensity, isogonics, isoclinics, isodynamics of components of intensity along axis of the lake and perpendicular to it, and isodynamics of total intensity.

[1] Erdmagnetische Messungen in der Umgebung des Balatonsees. Ausgeführt im Sommer 1901, von Dr. L. STEINER, Assistent der Kön. Ung. Meteorologischen Reichsanstalt. Repr. from "Resultate der wissenschaftl. Erforschung des Balatonsees." 1 Bd., 1 Theil, III Sec. Budapest, 1902. 21x29 cm.

[2] Kurländer used the same instrument in his survey of Hungary during 1892–4.

Digitized by Google

In Appendix I, the author discusses the advisability of making complete determinations of horizontal intensity at central stations and depending upon oscillations or deflections alone, counting upon a uniform change in m, for intermediate stations. Taking m as constant during his work and calculating values of intensity "A" from nineteen observations of oscillations with two magnets each and values "B" from a corresponding number of deflections; the mean value of $A-B$ is but 7γ indicating that the scheme of observation of deflections or oscillations alone is feasible under favorable conditions. Still for trips involving considerable transportation of instruments, the absolute method is always to be preferred.

In a second appendix are given the methods and results by G. Marczell in determining magnetic moments of samples of rock from the various stations. The weak magnetic properties of the samples made necessary that the deflected needle be held in position by a very weak field: this was accomplished by two electro-magnets north and south of the suspended needle, so reducing the Earth's field to $\frac{1}{10} - \frac{1}{50} H$.

J. A. FLEMING.

U. S. C. AND G. S.

EXPERIMENTAL RESEARCHES ON DRAWN STEEL.—PART I. MAGNETISM AND ITS CHANGES WITH TEMPERATURE.—PART II. RESISTIVITY, ELASTICITY, AND DENSITY, AND THE TEMPERATURE COEFFICIENTS OF RESISTIVITY AND ELASTICITY.[1]

BY J. REGINALD ASHWORTH.

(Abstract.)

PART I.

In a former paper[2] it was shown that the variation of the intensity of magnetization of a magnet under fluctuations of temperature is controlled to a large exteut by the self-demagnetizing factor of the magnet, the self-demagnetizing factor being governed by the dimension ratio. In general, an increment of temperature in the cyclic state reduces and a fall of temperature augments the magnetic intensity, so that a in the equation

$$I_{t'} = I_t \ (1 + a \ \overline{t' - t})$$

is negative, t' being a greater temperature than t and $I_{t'}$ and I_t the corresponding magnetic intensities. But it was discovered that magnets made of pianoforte wire, in the commercial state, more than 50 diameters long, exhibited a positive or incremental coefficient. If the magnet were much shorter the coefficient was decremental, and, for an intermediate dimension ratio, zero.

In the present paper a complete experimental investigation of the temperature coefficient of a magnet is undertaken. Attention is at first confined to pianoforte steel wire, and tables and curves are given of the change of a, and the change also of I, as the dimension ratio is increased from about 16 to 100 for the wire in three conditions—namely, annealed, glass hard, and commercial drawn state.

[1] Communicated to the Royal Society by PROFESSOR SCHUSTER, F. R. S., and read March 6, 1902.

[2] See *T. M.*, Vol. II, 137.

Digitized by Google

In the first two the coefficient is decremental, and, in magnitude, large for annealed and very small for glass hard; but in the drawn state α changes from decremental to incremental as the dimension ratio advances. It thus appears that the drawing is responsible for the peculiar behavior of α.

To confirm this, experiments were made on twelve samples of pianoforte steel, representing every stage in the process of drawing from the rolled rod through annealing and tempering to the fine-drawn wire, the drawing being carried one or two steps farther than is usual in commercial practice. The experiments were made on lengths of 50 and 100 diameters. The curves which are traced show very clearly that α changes in sign at a not very advanced stage in the drawing, grows more positive, reaches a maximum, and then droops towards zero again at extreme drawing. The magnetic intensity rises steadily with drawing, and shows no tendency to diminish even at the final stage of drawing; it is then about 200 per cent greater than at the first drawing.

An examination of a piece of drawn steel wire about 400 diameters long then follows, in which susceptibility and intensity are determined when the wire was at air temperature and when it was at 100° C.

The effect of heating is very pronounced, and, unlike the general behavior of iron and steel, the hot curve of magnetization is always above the cold curve, as the steel is carried to its greatest intensity and brought to its residual condition by the withdrawal of all force. Thus it retains more magnetism hot than cold. But on demagnetizing, the hot curve droops faster than the cold curve, and the curves intersect when the reversed force is about 4 C. G. S. units, and at this point the magnetic intensity is the same hot or cold. The explanation of the fact that a self-demagnetizing force of given amount produces a zero temperature coefficient in drawn steel now becomes clear.

The influence of magnetic intensity on the magnitude of α is next investigated in a long series of observations. The wire was magnetized step by step, and at each step the temperature coefficient and the percentage permanent change of intensity were determined, both for induced and residual intensity. The temperature coefficient in general follows the susceptibility, and becomes least at the highest intensity, but always incremental; on demagnetizing it increases slightly, and then falls towards zero, which occurs at some very low residual intensity.

The behavior of the residual magnetism as demagnetization proceeds is very interesting; when a small part of the magnetism is removed, the effect of alternate heatings and coolings is to leave the intensity higher than before the application of heat and cold, and the more the magnetism is removed the greater the recovery by heating and cooling; and, at last, on applying so large a demagnetizing force as to remove all the magnetism and to leave a small residual intensity inverse to the direction of the original intensity, then heatings and coolings clear this out and restore some of the original magnetization. The behavior of the coefficient during these changes is also discussed.

For comparison, the same series of experiments was performed upon an annealed iron wire about 400 diameters long. The hot curve of magnetization crosses the cold curve a little beyond maximum susceptibility, and the maxi-

Digitized by Google

mum residual intensity is less hot than cold; it would, therefore, appear that at some small initial intensity the coefficient should be positive, at a later stage zero, and, finally, negative. The zero coefficient was not obtained in these experiments, but the subsequent negative coefficient was traced, and it was found that when the susceptibility is large the negative coefficient is a minimum; the coefficient is throughout negative during demagnetization.

The intensity under heating and cooling is similar in behavior to the intensity of drawn steel; on magnetizing, heatings and coolings always cause a loss of residual magnetism, but on demagnetizing, heatings and coolings restore some of the magnetism removed. It would no doubt be advantageous for the sake of producing a magnet of constant intensity to apply a small reversed force after magnetizing to saturation; any fluctuations of temperature afterwards would then tend to increase rather than diminish the intsensity.

It is pointed out that the gradual decay of magnetism in observatory magnets will generally be accompanied by some change in the coefficient, and that remagnetization of magnets will likewise alter the magnitude of the coefficient; the general effect of this change will be determined by the position of the point of intersection of the hot and cold curves of magnetization.

Observations, extending over several years, then follow on four magnets made of drawn steel and treated in two different ways so as to have nearly zero coefficients, and the effects of time and the effects of remagnetization on the temperature coefficient and on the intensity are studied.

PART II.

The series of wires representing the twelve stages in the manufacture of drawn wire were subjected to examination for resistivity and its temperature coefficient, for Young's modulus and its temperature coefficient, and for density.

Resistivity is augmented by tempering but diminished by drawing up to a certain stage; extreme traction, however, causes a rapid increase again of resistivity.

The temperature coefficient is related to the resistivity, so that, in general, high resistivity and low coefficient are associated. Drawing, however, does not produce a very large change in the temperature coefficient of resistivity.

Young's modulus increases markedly with tempering and to a less extent with drawing up to the point where the resistivity is a minimum; after that, extreme drawing produces a sharp diminution of the modulus.

The temperature coefficient of Young's modulus presents an interesting relation to the modulus and like the resistivity coefficient follows in an inverse sense the modulus curve, so that when the modulus is large the coefficient is small.

It was observed that after heating and cooling the wire the value of Young's modulus did not return to its initial value, but was always a little greater; perhaps this was not a permanent effect, although it persisted for some time.

A careful series of determinations on the density of the wires showed that, with some initial irregularities, the density is very decidedly increased by drawing to the very last stage, when it becomes 8 grammes per c. cm.

There is a very close correspondence between density and magnetic

Digitized by Google

intensity, the two being nearly proportional to one another over a considerable range; there is also some evidence of agreement between a smooth curve of Young's modulus and the magnetic intensity; both appear to be functions of the density.

MAGNETIC OBSERVATIONS AT POLA OBSERVATORY IN 1901.[1]

This publication presents in a very complete and interesting form the results obtained from the magnetograph records of the year. The equipment comprised a unifilar, a bifilar, and a balance, which were in continuous operation throughout the year except on three occasions when the records were interrupted for about a day each time owing to the light going out or becoming defective. For the first seventeen days in January the results from the unifilar are unreliable owing to the formation of a hairlike fungus growth in the magnet house, due to the unavoidable dampness of the underground observatory. The same thing occurred in July, 1902, at the Baldwin Magnetic Observatory of the U. S. Coast and Geodetic Survey, where the instruments (Eschenhagen pattern) are mounted in an extemporized structure partly underground.

There are given in full the monthly tabulations of the hourly values of declination, horizontal intensity and vertical intensity also the daily, hourly, and monthly means, daily maximum and minimum values, and daily range. The character of the curve, a. m. and p. m., is indicated by numbers corresponding to the degree of disturbance. The monthly means are as follows:

1901	D	H	Z	1901	D	H	Z	1901	D	H	Z
	° ′	γ	γ		° ′	γ	γ		° ′	γ	γ
Jan.	9 22.68	22217.7	38874.5	May	9 20.50	22229.5	38843.0	Sept.	9 19.78	22236.4	38852.4
Feb.	22.08	15.1	61.0	June	19.91	33.3	48.0	Oct.	18.82	31.3	36.8
Mar.	21.48	20.2	46.5	July	19.76	47.1	65.3	Nov.	18.26	32.0	27.1
Apr.	21.12	22.9	37.7	Aug.	19.37	43.4	55.7	Dec.	17.91	32.1	27.6

And the mean daily range:

1901	D	H	Z	1901	D	H	Z	1901	D	H	Z
	′	γ	γ		′	γ	γ		′	γ	γ
Jan.	2.87	21.8	16.5	May	9.44	28.6	25.9	Sept.	8.04	33.8	22.8
Feb.	4.92	26.4	12.0	June	9.33	31.8	25.3	Oct.	7.07	24.2	19.0
Mar.	7.74	24.9	21.3	July	8.56	31.3	25.1	Nov.	4.42	22.6	12.5
Apr.	9.64	26.1	28.8	Aug.	8.68	34.9	19.8	Dec.	3.49	21.6	13.3

[1] Jahrbuch der Meteorologischen, Erdmagnetischen und Seismischen Beobachtungen, Neue Folge, VI. Band. Veröffentlichungen des Hydrographischen Amtes der Kaiserlichen und Königlichen Kriegs-Marine in Polo.

Digitized by Google

Other tables give the means of the hourly differences from the monthly mean for declination, horizontal intensity, vertical intensity, inclination, total intensity and X and Y components. Still other tables give the number of disturbed hourly values and their distribution over the day.

The absolute observations were made at varying intervals averaging seven days apart for declination, twelve days for horizontal intensity, and six days for inclination. The results are given in tabular form. The values of the D, H, and Z base lines for each day of the year are also tabulated.

In an appendix there are curves showing how the daily ranges are affected by the seasons. There are also curves showing the distribution of disturbances over the day.

By comparing the monthly means from 1890 to 1901, the *following values of the annual change for the period 1899-1901 are derived:*

Declination (decrease in W. decl'n)	$-4.'9$	W. component	-26γ
		Inclination	$-1.'8$
Hor. intensity	$+31\gamma$	Vert. intensity	$+13\gamma$
N. component	$+36\gamma$	Total intensity	$+28\gamma$

In December, 1899, an iron roof was put on a building situated about thirty-five paces from the observatory. Special absolute observations were made to determine the effect on the magnetic elements. It was found that it required three months for the magnetic field to reach a stable condition.

The records of the year do not reveal any notable abnormal manifestations.

WM. F. WALLIS.

BALDWIN, KANSAS.

PHOTOGRAPHIC EFFECTS OF BECQUEREL RAYS IN THE ATMOSPHERE.

A concise account of work done in common with Prof. H. Geitel in showing the photographic and other effects of the radioactivity imparted to negatively charged conductors by contact with the atmosphere. Copper wires ten meters long suspended in the open are kept negatively charged to a few thousand volts for several hours. The wire is then taken in and rubbed briskly with a piece of leather dampened with ammonia water, this process transferring the radioactivity from the wire to the leather, which may be quickly dried over a flame without loss of activity. With the lapse of time the activity decreases rather rapidly, so that after twelve hours only a small fraction of the original activity remains. With five successive exposures of four hours each to pieces of leather made radioactive in this way, radiographs of a lead stencil were obtained on a photographic plate through aluminum foil 1-10 mm. thick. Leather can indeed be made so strongly active as to cause visible action on a fluorescent screen. It is pointed out that since the whole surface of the Earth is negatively charged with reference to the atmosphere, it is doubtless radioactive and continuously ionizing the surface layer of air.

G. B. PEGRAM.

[1] ELSTER, J. Ueber die Herstellung von photographischen Eindrücken durch Becquerelstrahlen, die der atmosphärischen Luft entstammen. Repr. from "Jahrbuch für Photographie und Reproductionstechnik, für das Jahr 1902." 7 pp. 12 x 19 cm.

Digitized by Google

RECENT PUBLICATIONS

BARACCHI, PIETRO. Results of observations in meteorology and terrestrial magnetism made at the Melbourne Observatory, and other localities in the State of Victoria, Australia, July 1,–Dec. 31, 1901. Melbourne, 1902. 52 pp., 15½ x 24½ cm.

Contains following magnetic results:

Date. 1901.	Melb. M. T.	Decl'n. E.	Melb. M. T.	Incl'n. S.	Melb. M. T.	Hor. I. (c. g. s. units.)	Vert. I. (c. g. s. units.)	Total I. (c. g. s. units.)
	h m	° ′	h m	° ′	h m			
Sept. 20	12 22ƒ	8 26.68	4 05ƒ	67 24.98	11 05	.23305	.56024	.60679
" 23	.....	.....	3 17ƒ	26.83	.....	.....	.....	.....

BELGIQUE, OBSERVATOIRE ROYAL DE. Annuaire Météorologique pour 1903 publié par le soins de *A. Lancaster*, Directeur du Service météorologique. Bruxelles, 1903. Pp. 662, 10 x 14 cm. [Pp. 408–409, annual values of the magnetic elements at Uccle, 1895–1902.]

CREAK, E. W. Elementary Manual for the Deviations of the Compass in Iron Ships. J. D. Potter, London, 1903. Pp. 150, and 4 charts. 16 x 24 cm.

CORTIE, A. L. Minimum sun-spots and terrestrial magnetism. Repr. Astrophys, J., vol. XVI, 1902, pp. 203–210.

DUKE OF THE ABRUZZI. Osservazioni scientifiche eseguite durante la spedizione polare di S. A. R. Luigi Amedeo di Savoia Duca degli Abruzzi 1899–1900. Ulrico Hoepli, Milan, 1903. Large 8°, 724 pp. [This sumptuous volume contains the scientific results of the polar expedition, 1899–1900. The two chapters of interest to magneticians are: Pp. 195–207, Aurore boreali; and pp. 435–501, Osservazioni magnetiche. Reviews of these will appear later.]

MACKENZIE, A. STANLEY. An instrument for drawing a sine curve. Phys. Rev. Dec., 1902, p. 366.

POTSDAM MAGNETISCHES OBSERVATORIUM. Ergebnisse der magnetischen Beobachtungen in Potsdam im Yahre 1900. Veröffentlichungen d. K. Preuss. Meteorol. Inst., (W. von Bezold, Director) 1900. Heft. 2. Berlin, 1902. 44 pp. and 4 pl. 25 x 33 cm. [Contains the usual hourly tabulations of the magnetic elements, their variations and perturbations, and 4 plates of diagrams.]

RED SEA MAGNETIC OBSERVATIONS. Magnetische beobachtungen; expedition S. M. schiff "Pola" in das Rothe meer (September 1897–Marz 1898). (*C. Rössler*) Commission für oceanographische forschungen: Berichte 7, 221 (1901).

SCHUSTER, ARTHUR. The solar atmosphere. Repr. Astrophs. J., vol. XVI, 1902, pp. 320–327.

ROTCH, A. L. The circulation of the atmosphere in the tropical and equatorial regions. Repr. Monthly Weather Review, April, 1902. 44 pp. and 2 figs. 14½ x 23 cm.

TOKYO. Publications of the Earthquake Investigation Committee in Foreign Languages. Nos. 7 and 11. 1902. [Contents of No. 7: *A. Tanakadate*, vertical motion seismometer; *A. Imamura*, seismic triangulation in Tokyo; *A. Imamura*, a mechanical starter; *F. Omori*, note on the aftershocks of the Mino–Owari earthquake of Oct. 28, 1901; appendix, list of earthquakes observed at Nemuro. Contents of No. 11: *F. Omori*, macro-seismic measurement in Tokyo. II and III.]

Digitized by Google

THE NEW YORK
PUBLIC LIBRARY,
ASTOR, LENOX AND

Digitized by Google

J. J. Thomson

Digitized by Google

THE NEW YORK PUBLIC LIBRARY.
ASTOR, LENOX AND TILDEN FOUNDATIONS

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VIII JUNE, 1903 NUMBER 2

THE CAUSE OF THE EARTH'S MAGNETISM.

By William Sutherland.

In this Journal for June, 1900, it was shown that a sphere of radius a charged with electricity of volume density ρ, and revolving round an axis with angular velocity Ω, would have a magnetic potential at a point r, θ where θ is the colatitude,

$$\int_o^a \frac{4}{3}\pi\Omega\cos\theta\,\rho\,R^4\,dR/r^2. \qquad (1)$$

If an equal amount of the opposite sort of electricity were distributed through a sphere of radius $a - da$, its volume density ρ' would be determined by the condition,

$$\rho'(a-da)^3 = \rho a^3; \text{ hence, } \rho' = \rho(1 + 3\,da/a), \qquad (2)$$

and its magnetic potential would be,

$$\int_o^{a-da} \frac{4}{3}\pi\Omega\cos\theta\,\rho(1+3\,da/a)R^4\,dR/r^2.$$

The magnetic potential of the two distributions together would be

$$\frac{4}{3}\pi\Omega\frac{\cos\theta}{r^2}\left\{\rho_a\,a^4\,da - \frac{3\,da}{a}\int_o^a \rho\,R^4\,dR\right\}.$$

If ρ is assumed to be not a function of R, this becomes

$$\frac{8}{15}\pi\Omega\,\frac{\cos\theta}{r^2}\,\rho\,a^4\,da. \qquad (3)$$

This is the right form of expression for the average magnetic potential round parallels of latitude on the Earth's surface.

Digitized by Google

J. J. Thomson

Digitized by Google

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 8. JUNE, 1903 NUMBER 2

THE CAUSE OF THE EARTH'S MAGNETISM.

By William Sutherland.

In this Journal for June, 1900, it was shown that a sphere of radius a charged with electricity of volume density ρ, and revolving round an axis with angular velocity Ω, would have a magnetic potential at a point r, θ where θ is the colatitude,

$$\int_0^a \frac{4}{3}\pi\Omega\cos\theta\,\rho\,R^4\,dR \quad r^2. \qquad (1)$$

If an equal amount of the opposite sort of electricity were distributed through a sphere of radius $a-da$, its volume density ρ' would be determined by the condition,

$$\rho'(a-da)^3=\rho a^3; \text{ hence, } \rho'=\rho(1-3\,da/a) \qquad (2)$$

and its magnetic potential would be,

$$\int_0^{a-da}\frac{4}{3}\pi\Omega\cos\theta\,\rho(1-3\,da/a)\,R^4\,dR \quad r^2.$$

The magnetic potential of the two distributions together would be

$$\frac{4}{3}\pi\Omega\frac{\cos\theta}{r^2}\left\{\rho a^4\,da-\frac{3\,da}{a}\int_0^a\rho R^4\,dR\right\}.$$

If ρ is assumed to be not a function of R, this becomes

$$\frac{8}{15}\pi\Omega\frac{\cos\theta}{r^2}\rho a^4\,da. \qquad (3)$$

This is the right form of expression for the average magnetic potential round parallels of latitude on the Earth's surface.

Digitized by Google

As to the two distributions of electricity throughout the substance of the Earth, we have now strong evidence. In Helmholtz's theory of chemical valence of the atoms, each bond between the atoms in a molecule is supposed to consist of two opposite electrons associated with the atoms. For convenience I have proposed (*Phil. Mag.*, Feb., 1902) to denote the positive electron by ♯ and the negative by ♭. With the aid of this notation, Helmholtz's theory can be summarized by writing the chemical formula for *NaCl* in the form *Na*♯♭*Cl*, in which *Na*♯ and ♭*Cl* are the two ions into which *NaCl* is resolvable. I have sought to show (*Phil. Mag.*, Dec., 1902) that all the phenomena of cohesion can be traced to these electric doublets ♯♭ in molecules, for they act as the electric analogues of minute magnets.

Thus, then, every ordinary molecule involves in its own existence that of at least one ♯ and one ♭. The whole Earth, then, contains two opposite enormous charges of electricity. These charges are so nearly equally distributed throughout the Earth that they produce no external electrical effect; they help to hold the atoms together in chemical combination, and they cause the cohesion of the Earth's material with the assistance of gravitation. If the two charges of electricity were distributed through the Earth in absolute equality, their magnetic fields would exactly neutralize one another, and we should have no terrestrial magnetism. It is of importance therefore to inquire what difference in the distributions of the Earth's two charges of electricity would be required to account for its magnetic field. With this end in view the opposite charges were supposed above to be distributed through spheres of radii a and $a—da$. For the average magnetic potential Ψ, in electro-magnetic units, round a parallel of latitude $\pi/2 - \theta$, in 1880 von Bezold has given

$$\Psi = .330\, a \cos\theta.$$

Accordingly we have from (3) with $r = a$ at the surface of the Earth, and with c for the velocity of light

$$\frac{8}{15}\pi\,\Omega\,\rho\,a\,da = .330\,c. \qquad (4)$$

Now we can determine the order of magnitude of ρ by the following argument. Each molecule of the Earth contains at least one ♭, the amount of whose charge is usually denoted by e. We may take the average molecular weight of the Earth's substance to

Digitized by Google

be in round numbers 100, so that, if h is the actual mass of an atom of hydrogen, the mass of the average molecule in the Earth is $100\,h$. But the whole mass of the Earth is $4\,\pi\,D\,a^3/3$, where D is its mean density, so the total number of molecules in the Earth is $4\,\pi\,D\,a^3/300\,h$, and therefore the total charge of negative electricity in the Earth is $4\,\pi\,D\,a^3\,e/300\,h$, and its density ρ is $De/100\,h$. But e/h is a fundamental electrical constant having the value $10^{17}/345$, and

$$a = 637 \times 10^6\ cm.,\ \Omega = 2\pi/24 \times 60 \times 60,\ D = 5.7,\ \text{and}\ c = 3 \times 10^{10}.$$

These values in (4) furnish the value 8×10^{-9} for da. But the order of magnitude for the diameter of ordinary molecules is about 10^{-8} *cm*, and (*Phil. Mag.*, Dec., 1902) this seems to be about the distance between ♯ and ♭ in a binary molecule. Thus we have found that if the negative and the positive electricity in the Earth are spread over concentric spheres whose radii differ by only the diameter of a single molecule, they can account for the Earth's primary magnetic field. This separation of the two electricities would produce no external electric effect. It implies a minute tendency of each ♭ of a molecular doublet to turn farther from the center of the Earth than ♯ does.

In my paper of June, 1900, above cited, a cosmical separation of large charges of the two electricities in the interior of the Earth was treated as a possible cause of its magnetism. Now I would propose that an inequality in the distribution of its atomic charges, such as has just been considered, is a much more probable cause. We know that the Earth does contain two enormous opposite charges of electricity, which are almost certainly in rotation with it. It remains now only to prove that there must be such an inequality in the distributions of the two charges as we have briefly investigated, in order to demonstrate that the atomic electric charges are the true source of the Earth's magnetism. Helmholtz suggested that to account for the contact difference of electric potential in metals, we must suppose atoms to exert different attractions on the two sorts of electron. Many physicists see in the cathode rays evidence that the metals attract negative electricity less than positive. J. J. Thomson has pointed out (*Phil. Mag.*, [5] xxxvii, p. 358) that if there is this difference of attraction for the two electricities in the atom, then a large rotating body should generate a magnetic field. Kelvin and other physicists have suggested that magnetism may be a property of rotating masses,

Digitized by Google

which becomes measurable only when the masses are large enough. From our equation (3) we can estimate what ought to be the magnetic field of any heavenly body of which we know the radius a, the angular velocity of rotation Ω, and also the density D, with which to estimate the electric density ρ as we have done above. Until we know more, it will be simplest to assume either that da is the same for all heavenly bodies, or is proportional to their masses.

On the present theory magnetism must be a property of all rotating bodies. It is the comparatively minute outstanding difference between the two opposite magnetic fields generated by the opposite electricities associated with matter. In this aspect it reminds one of surface-tension, which reveals the play of molecular forces that escape ordinary observation.

With the aid of equation (3) it is possible to show that the effects of the Sun's magnetic field on the Earth are beyond our existing means of detection. The Sun's effect on terrestrial magnetism must be indirect, as is the prevailing opinion. Concerning the Sun's magnetism, special importance attaches to Bigelow's location of the solar magnetic poles by means of the polar rays of the corona shown in eclipse photographs and drawings. The solar magnetic poles, like the terrestrial, do not lie in the axis of rotation, nor do they lie on a diameter. The repetition of the magnetic asymmetry of the Earth in the solar magnetic field is an important fact in planetary magnetism.

To carry the present theory of stellar magnetism farther, the main desiderata are (1) a demonstration of the difference in the attraction of matter for the two sorts of electricity, and (2) determination of the law of attraction between matter and electricity, to ascertain whether it is such as to cause negative electrons in molecules to take up a position which on the average is farther from the center of the Earth than that taken by positive electrons.

Melbourne, June, 1903.

Digitized by Google

AN ANALYSIS OF THE RESULTS FROM THE KEW MAGNETOGRAPHS ON QUIET DAYS DURING THE ELEVEN YEARS 1890–1900, WITH A DISCUSSION OF CERTAIN PHENOMENA IN THE ABSOLUTE OBSERVATIONS.[1]

By Charles Chree, Sc. D., LL. D., F. R. S., Superintendent of the Observatory Derartment.

[Author's Abstract.]

The late Kew Observatory Committee joined in 1890 in a scheme whereby five days each month were to be selected as magnetically *quiet* days by the Astronomer Royal, with a view to the curves on these days being tabulated by observatories which did not care to undertake the tabulation of every day's curves. That scheme has been persisted in, and the present paper deals with the results it has led to during the eleven years 1890–1900. The paper treats of the secular change in the several elements, of the annual inequality, of the diurnal inequality, and the non-cyclic effect in the diurnal variation. Attention is more particularly given to the declination, inclination, and the horizontal and vertical components, but some consideration is also given to the northerly and westerly components of the horizontal force and to the total force.

Diurnal inequalities are got out for each month of the year in the principal elements. These inequalities are analysed into Fourier's series, and the variation of the Fourier co-efficients is traced throughout the year. Attention is also given to the variation throughout the year in the ranges of the diurnal inequalitiies and in the sum of the twenty-four hourly differences from the mean for the day. The diurnal inequalities are shown graphically in various ways, serving to illustrate different features.

As explained in a "Preliminary Note," the relation between magnetic phenomena and sun-spot frequencies have been investigated. The present paper treats of this investigation in detail. Attention is given to the ranges, and the sum of the twenty-four hourly differences from the mean of the day in the diurnal inequalities, and to the amplitudes and phase angles of the terms in the Fourier series representing these inequalities. Some of the results obtained for Kew are compared with corresponding results for Wilhelmshaven and Parc St. Maur, based on data given by Börgen and Moureaux. The results from the stations compared showed a very good agreement.

It is found that the non-cyclic effect in the diurnal variation, and the

[1] Received May 1, and read May 28, 1903, before the Royal Society.

Digitized by Google

variability in the declination—recently discussed by the author in connection with the observations of the "Southern Cross" Antarctic Expedition—show a relation to sun-spot frequency similar to that observed in the ranges of the diurnal inequalities themselves.

A comparison is made between magnetic and meteorological phenomena at Kew from two groups of years, the one representing large, the other small sun-spot frequency. This serves to bring out the insignificance of the connection between meteorological phenomena at a given station and sun-spots—if any such connection exists—as compared to the connection between magnetic phenomena and sun-spots.

A comparison is instituted *inter alia* between the variation throughout the year in the amplitude of the Fourier co-efficients in the series found for diurnal inequalities of the magnetic elements and atmospheric temperature, making use of the temperature data discussed by General Strachey. It is shown that the amplitudes of the twenty-four hour term in the Fourier series in the two cases vary in a very similar fashion throughout the year, but that this is not true of the twelve-hour, eight-hour, or six-hour terms. Attention is also called to the fact that, in the temperature diurnal inequality, the twenty-four-hour term preponderates in a way that is not found in any of the magnetic elements. The bearing of this is pointed out on theories as to the source of the magnetic diurnal inequality.

Attention is also drawn to the peculiarity in the variation from month to month in sun-spot frequencies, which enables a somewhat searching inquiry to be made as to the simultaneity of changes in sun-spot frequency and magnetic ranges.

A final section deals with the true nature of the connection between sun-spot frequency and magnetic phenomena. A comparison is made between Wolfer's provisional sun-spot frequencies for all days in the year and for the Astronomer Royal's magnetically quiet days. The conclusion come to is that sun-spot frequency on any particular day is no guide to the magnetically quiet or disturbed character of the day, and that even mean results for a month for sun-spot frequency and magnetic ranges are but slightly related. It is pointed out that the phenomena observed would be consistent with the view that increased sun-spot activity and increased magnetic activity on the earth are due to some common source external to the sun, whose effect at the same instant varies appreciably throughout the solar system. If the source lies in the sun itself, it is concluded either that sun-spots afford no satisfactory quantitative measurement of it, or else that the effect at the earth is influenced by what takes place at the sun during a considerable time. If the source of the magnetic diurnal inequality be, as has been suggested by various physicists, electrical currents generated by the sun's action in the upper atmosphere, the cause of the increase in the amplitude of the inequality at

Digitized by Google

times of great sun-spot frequency may be some form of radiation which reduces the resistance of the atmosphere to currents generated by the sun. This would explain the phenomena without requiring the enormous variations in the sun's output of energy from year to year that would appear necessary to account for the great variations in the magnetic phenomena, variations moreover which—as the paper shows—do not appear to be accompanied by any but the most insignificant changes in the amplitude of the temperature inequality at the earth's surface. The importance is pointed out of reliable information as to whether atmospheric electricity potential, at low and at high levels, resembles magnetic phenomena in being largely different in years of large and small sun-spot frequency.

NATIONAL PHYSICAL LABORATORY.

Digitized by Google

ADOLF SCHMIDT'S CHARTS OF THE EARTH'S MAGNETIC COMPONENTS FOR 1885.[1]

The usual iso-magnetic charts give the lines of equal magnetic declination, of equal magnetic inclination, of equal horizontal intensity, or of equal total intensity. Schmidt makes a welcome addition to this customary list by contributing the charts giving the lines of equal northerly components (X), equal easterly components (Y), and of equal vertical components (Z) as based upon the computed quantities resulting from his harmonic analysis of the Earth's magnetic field for 1885; these computed quantities of X, Y, and Z for every 5° in latitude and longitude are published in "Aus dem Archiv der Deutschen Seewarte," 1898.

A superficial glance at the accompanying figures show that the *general* appearance of the chart of the X component (the magnetic force component directed due north or south) is that of the horizontal intensity chart, whereas that of the Y component (the force component directed due east or west) resembles in a general way the isogonic chart and that of the Z component (the force component directed vertically downwards or upwards) the isoclinic chart; a more minute examination will, however, reveal striking departures.

Both X and Y vanish at the magnetic poles, the positions of which as determined by Schmidt's analysis are: Magnetic North Pole: Latitude, 71° 10′ N., Longitude, 95° 38′ West of Greenwich; Magnetic South Pole: Latitude, 75° 39′ S., Longitude, 148° 27′ East of Greenwich.

At the *geographical* poles we have, as expressed in c. g. s. units:

North Pole	South Pole
$H = 0.04978$,	$H = 0.10008$
$X = 0.04978 \cos(\lambda - 58° 47')$,	$X = 0.10008 \cos(-\lambda + 334° 38')$
$Y = 0.04978 \sin(\lambda - 58° 47')$,	$Y = 0.10008 \sin(-\lambda + 334° 38')$
$Z = 0.57860$,	$Z = -0.62651$

The maximum values of the northerly component X are 0·385 (in the Gulf of Siam) and 0.360 (vicinity of Galapagos Islands), the maximum easterly component Y is 0.087 in the northern hemisphere and 0.106 in the southern, whereas the minimum easterly component (i. e., maximum westerly component since Schmidt regards Y positive eastward) is 0.091 in the northern hemisphere and 0.107 in the southern. The maximum vertical component is 0.634 (northern hemisphere) and the minimum —0.674 (southern hemisphere).

The scale of the maps in figures 1, 2, and 3 is for the equator 1/200000000 and at latitude 60°, 1/100000000, whereas the scale for figure 4 is 1/100000000.

[1] Bemerkungen zur Karte der Linien gleicher Werte der erdmagnetischen Komponenten von DR. AD. SCHMIDT, Repr. Petermann's Geogr. Mitteilungen, 1898, Heft VII. 5 pp. and chart.

Digitized by Google

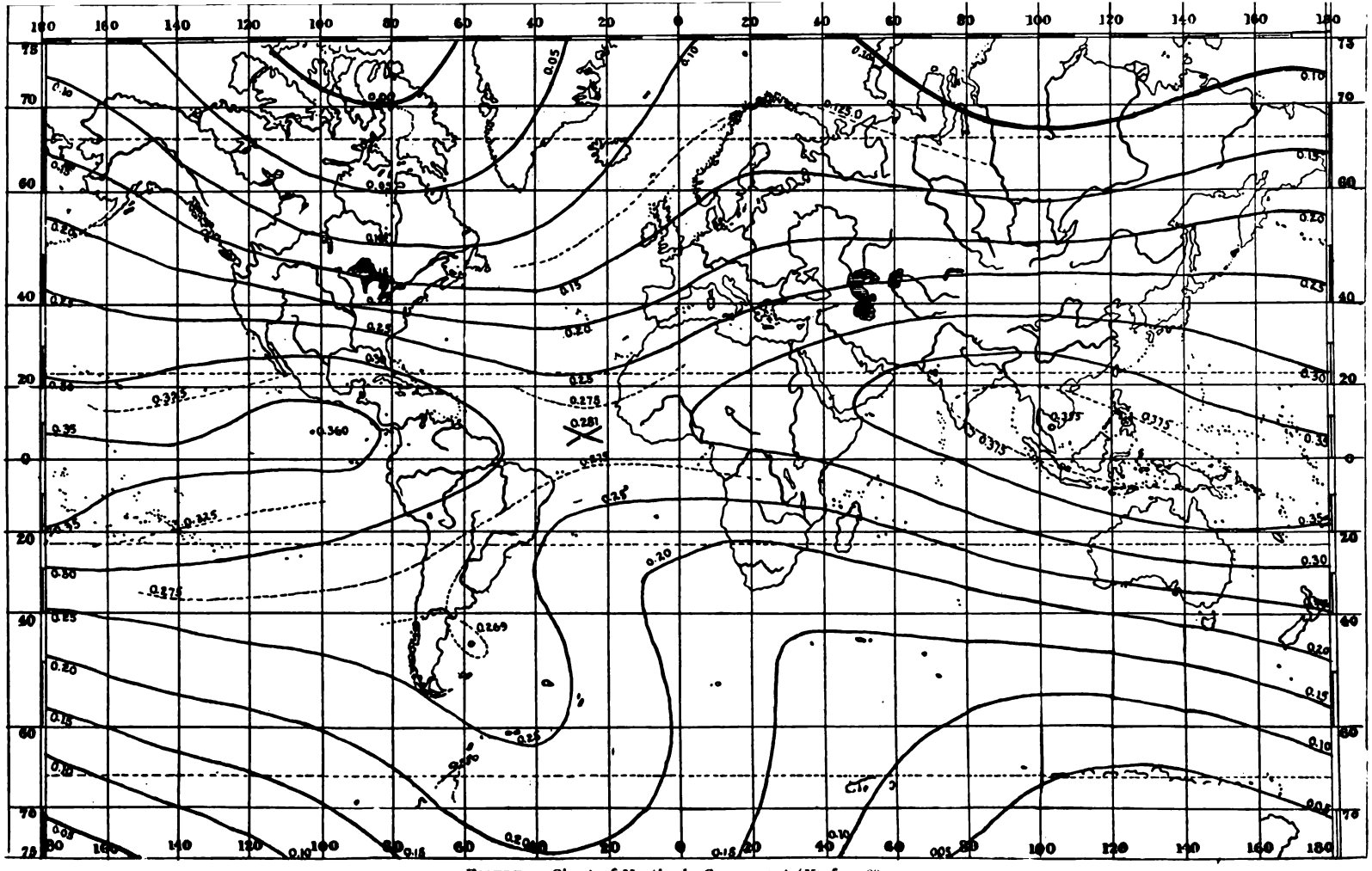


FIGURE 1. Chart of Northerly Component (X) for 1885.

Digitized by Google

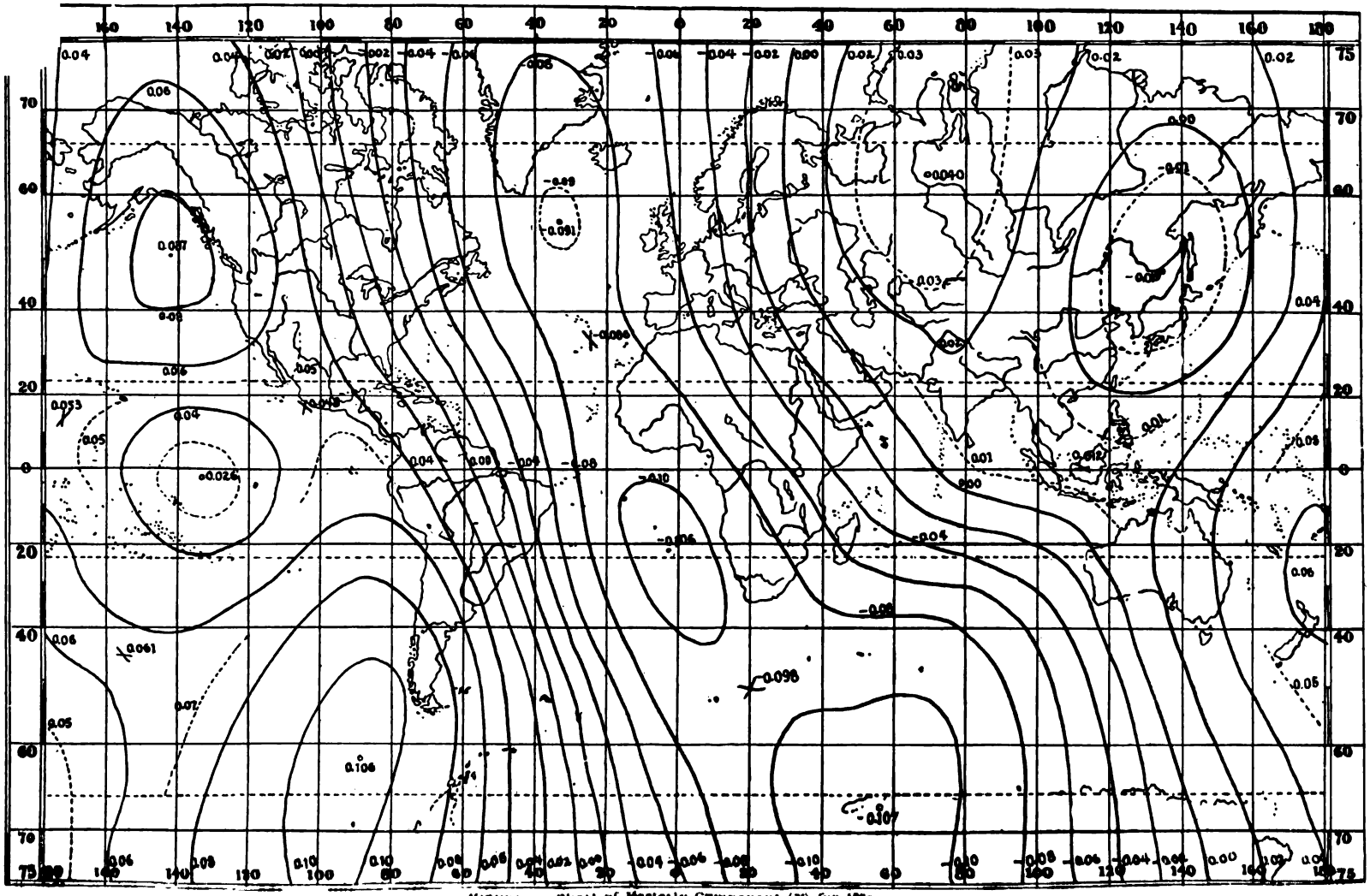
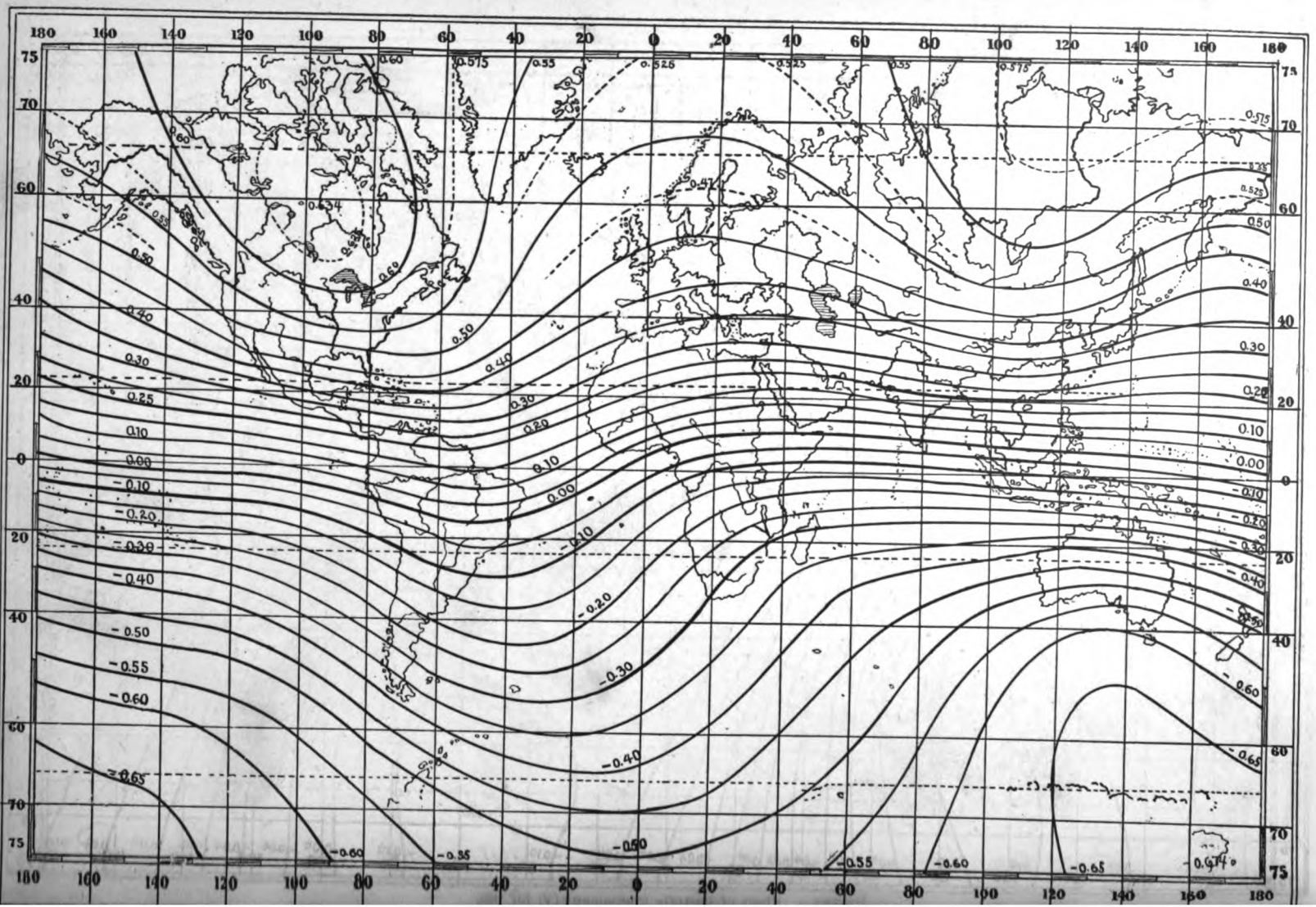


FIGURE 4. Chart of Westerly Component (Y) for 1885.

Digitized by Google



Digitized by Google

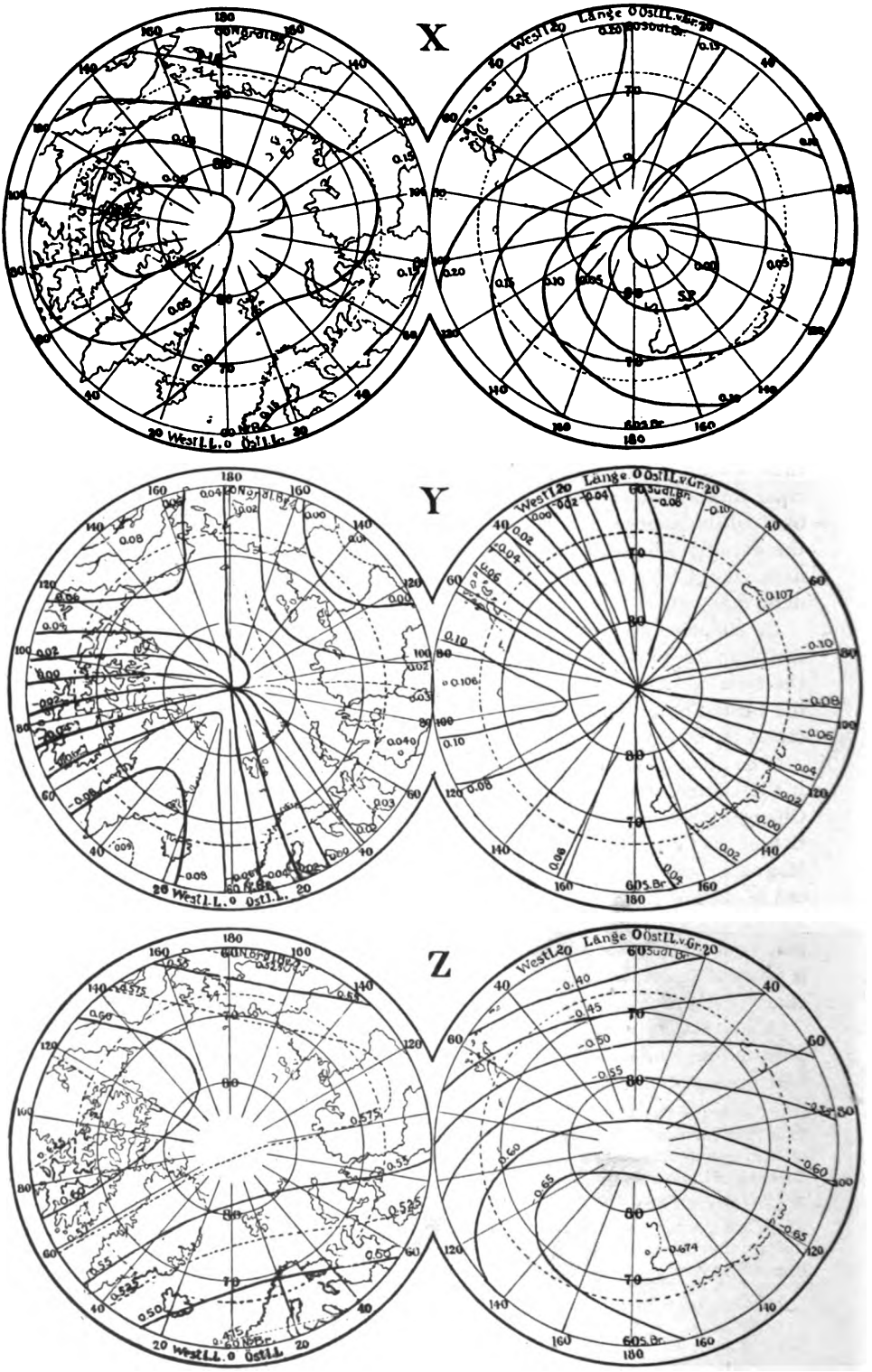


FIGURE 4. The Components in the Polar Regions for 1885.

Digitized by Google

RESULTS OF THE MAGNETIC OBSERVATIONS IN THE UNITED STATES UP TO JUNE 30, 1902.

By L. A. Bauer and D. L. Hazard.

Two recently issued publications bring the results of the magnetic (declination, dip, and intensity) in the United States up to the date, June 30, 1902.

The "Magnetic Declination Tables for 1902," cited in the foot-note below,[1] is a continuation of the series of papers begun in 1855, treating of the magnetic declination in the United States, the last one published having been by the late Mr. Schott in the year 1897 and giving the results for 1900. The form of publication has been altered into the more convenient octavo form.

To meet the demand for general information regarding the Earth's magnetic phenomena, the present tables have been prefaced by a historical and descriptive summary, accompanied by numerous and pertinent illustrations of the principal facts of the Earth's magnetism.[2] The principal topics treated under this head are: Early history of the compass, birth of the science of terrestrial magnetism, the Earth, a great magnet, the variations of the Earth's magnetism, magnetic observatories, magnetic charts, magnetic surveys, and the Earth's magnetic poles and magnetic moment.

A chapter has been added giving briefly methods for determining meridian lines and the magnetic declination, and in another are set forth the facts concerning the secular change of the magnetic declination in the United States and outlying territories, accompanied by the necessary tables of the amount of change for various periods.

The accompanying Chart of the "Lines of Equal Magnetic Declination in the United States" contains, in addition, the "Lines of Equal Annual Change," thus adding greatly to the convenience in the practical utilization of the Chart. With their aid the corrections to the "Lines of Equal Magnetic Declination" for any subsequent year prior to the next edition can readily be made. The Chart, as stated in its legend, is based on all known observations up to date, and refers to January 1, 1902. The base map contains sufficient physical features and names of towns to render it possible to locate readily on the map any desired place. An isogonic chart of Alaska is also given.

The "Magnetic Declination Tables," forming the main body of the publication, contain about 8,000 entries, and are the most complete tabular presentation of declination values in the United States.

[1] United States Magnetic Declination Tables and Isogonic Charts for 1902, and Principal Facts relating to the Earth's Magnetism by L. A. Bauer, Chief of Division of Terrestrial Magnetism. Separate Publication of the United States Coast and Geodetic Survey, *O. H. Tittmann*, Superintendent, Washington, 1902. 406 pp. 20 x 29 cm. 29 figs. in thetext and 3 plates.

[2] How general the demand for such information has been may be judged from the fact that the entire edition of four thousand copies of this publication has already been exhausted, and a second edition is now in the press.—Ed.

Digitized by Google

"Descriptions of the Coast and Geodetic Survey Magnetic Stations occupied between 1881 and June 30, 1902," conclude the publication. The descriptions of the stations previous to 1881 are contained in Appendix 9, Report for 1881.

The second publication[1] contains the results of dip and intensity observations between January, 1897, and June 30, 1902; those made prior to January, 1897, are contained in previous publications of the Coast and Geodetic Survey. The reduction to a common epoch is deferred pending the accumulation of additional secular variation data.

The publication of this paper and of the "Magnetic Declination Tables" alluded to above, mark, in a certain sense, the close of the initial period of the detailed and systematic magnetic survey of the United States and countries under its jurisdiction, which was inaugurated on May 1, 1899. During this period, from May 1, 1899, to June 30, 1902, a little over three years, all the instruments (16 dip instruments and 15 magnetometers), have been overhauled, modified, and improved whenever needed, and intercompared; four[2] magnetic observatories have been established and the instruments with which they are equipped have been carefully examined, tested, and put in operation. Field instruments of nearly every pattern now on the market (English, French, German, and Russian), have been purchased, critically studied, tested and compared, and a variety of investigations relating to instrumental constants, standardizations, and methods of observation have been made. Twenty persons have been trained in magnetic work, and, in addition to special field investigations, the magnetic elements have been determined at about 800 stations (about one-fifth of the total number proposed for the general magnetic survey) and the results have been prepared for publication.

The completion of this arduous initial work makes it possible to continue the magnetic survey (land and coast waters) and observatory work with unexcelled facilities and instrumental equipment. With this indication of future field activity, effort will be made to keep the office computations and reductions up with the observational work, as nearly as that is possible, so as to insure prompt publication of the results. The results obtained during any one fiscal year will hereafter be published in the Superintendent's report for that year.

In the present tables, the dip and intensity results were referred to standard instruments whenever possible. Some idea of the magnitude of these corrections will be obtained from the following exhibits:

[1] Results of magnetic dip and intensity observations made by the United States Coast and Geodetic Survey between January, 1897, and June 30, 1902, by DANIEL L. HAZARD, Computer, Division of Terrestrial Magnetism, with preface by L. A. BAUER, Inspector of Magnetic Work and Chief of Division of Terrestrial Magnetism. Appendix 6, Report of Superintendent *O. H. Tittmann* for 1902. Pp. 335, 336. Also published as a separate.

[2] A fifth was established in February, 1903, on Vieques Island, Porto Rico.—ED.

Digitized by Google

CORRECTIONS TO DIP CIRCLES ON THE SCHULZE EARTH INDUCTOR.

Circles.	Pattern.	Correction.	Used between
23. 34	Kew-Casella*	—0. 4	1900 Jan. and 1902 June
E I 22	Wild-Edelman	—0. 2	1901 Oct. and 1902 June
1. 1	Barrow	—0. 4	1900 Jan. and 1902 June
12. 12	Robinson-Barrow	+4. 2	" "
•15. 12	Kew-Casella*	—0. 8	1901 Sept. and 1901 Dec.
15. 24	"	+0. 5	1902 Jan. and 1902 June
18. 34 old	"	—1. 8	1900
18. 12 new	" *	+0. 4	1902 Apr. and 1902 June
20. 12 old	"	+0. 3	1900 Jan. and 1901 Feb.
20. 12 new	"	+0. 0	1901 Apr. and 1902 June
21. 12	"	+7. 2	1900 Apr. and 1900 Aug.
21. 12	"	+7. 0	1900 Aug. and 1900 Dec.
21. 12	"	+6. 0	1901 Jan. and 1902 June
24. 12	Moureaux-Chasselon	+6. 6	1901 June and 1902 June
25. 48	Eschenhagen-Tesdorpf	—3. 6	1901 Nov. and 1902 June
56. 12	Kew-Casella	—1. 9	1900 Jan. and 1900 May
56. 13	"	—0. 5	1900 May and 1901 June
56. 1234	"	—1. 4	1901 July and 1902 June
4655. 12	"	—0. 9	1900 Jan. and 1902 June
5676. 12	"	—4. 8	1900 Jan. and 1900 June
5676. 13	"	—5. 0	1900 June and 1901 May
5677. 12	"	—2. 4	1900 Jan. and 1901 May
5678. 12	"	—4. 5	1900 Jan. and 1902 June
5678. 23	"	—1. 9	1900 Mar. and 1900 May
5678. 34	"	—1. 0	1900 May and 1900 Aug.
5678. 1234	"	—0. 8	1900 Sept. and 1900 Oct.

In this table the following notation is used: circle 23.34 means that the number of the circle is 23 and the needles used are numbers 3 and 4. E I stands for Earth Inductor. Since the above corrections were obtained, a large Wild-Edelman observatory earth inductor (see this volume T. M., p. 28) has been installed in the Cheltenham Magnetic Observatory which will hereafter be the standard dip instrument, whereas the Schulze earth inductor will be the intermediate instrument by means of which comparisons of other circles will be made. These two earth inductors and a third, referred to in above table as E I 22, agree within a few tenths of a minute with each other.

All of the Casella dip circles had been purchased by the Survey before May 1, 1899; their needles are being replaced by new ones as rapidly as circumstances warrant.

Additional comparisons made since June 30, 1902, have not materially altered the corrections of the various dip circles.

ACCURACY OF RESULTS.

An examination of the above comparisons of dip circles shows that dip results uncorrected for instrumental error may be in error by 5′ or even more. As to error of observation purely, the same comparisons

*Needles by Dover.

Digitized by Google

show that in general the probable error of a single set (mean of two needles) does not exceed 1′. It may therefore be said roughly that dips up to 1899 are uncertain by 5′ and those since that time are probably within 2′ of the truth.

In the work of the Coast and Geodetic Survey prior to the beginning of a detailed magnetic survey of the United States it was considered satisfactory if the probable error of a resulting value of horizontal intensity did not exceed one part in five hundred. With the introduction of brass deflection bars and improved methods of observation the uncertainty has been reduced to 1/1000, and with more accurate determination of instrumental constants resulting from the intercomparison of different instruments, it may be still further reduced to 1/2000, or even less. These figures refer to a result from two sets of oscillations with two sets of deflections between, the whole operation occupying about an hour. Some further increase in accuracy can be attained by applying corrections for diurnal variation as the result of the continuous observations at magnetic observatories.

A comparison of the results of horizontal intensity observations made at the same station with the different instruments (especially at Washington, D.C.; Cheltenham, Md.; and Baldwin, Kan.) bears out the above estimated uncertainty of one part in one thousand. In the case of magnetometers Nos. 10, 20, and 21, however, the results were found to be systematically too small as compared with the other magnetometers, and all observations since April, 1901, with those three instruments have therefore been corrected as follows:

No. 10	$+0.003H$
No. 20	$+0.003H$
No. 21	$+0.008H$

The trouble with Magnetometer No. 21 (Moureaux-Chasselon magnetometer) was traced to impurities in the brass of which the magnet house is constructed, the time of vibration of the magnet differing materially when suspended in a magnetometer having a wooden magnet house. Similarly the large correction given in Table III for dip circle No. 24 (small Moureaux-Chasselon dip circle) was traced to impurities in the brass of the base and foot screws.

The above corrections constitute all that is warrantable, at present, toward reducing all intensity results to the same standard. As opportunity offers for further comparisons, however, it is intended to deduce for each instrument a systematic correction for reducing results by it to a standard instrument. The detailed results of the comparisons of the various dip instruments and magnetometers and their critical discussion will form the subject of a separate appendix.

Digitized by Google

LIFE AND WORK OF BENJAMIN FRANKLIN.[1]

Born,	January 17, 1706
Ran away to Philadelphia,	1723
Pennsylvania Gazette started,	1729
Philadelphia Library founded,	1731
American Philosophical Society founded,	1743
Projected University of Pennsylvania,	1743
Electrical Experiments,	1746–57
Postmaster-General of America,	1753
First Mission to England,	1757
LL. D. from Oxford and Edinburgh,	1762
F. R. S.,	1775
Died,	April 17, 1790

It is impossible in the time at our disposal to give more than a bare outline of the life of Benjamin Franklin. His chief work was as a politician, statesman and diplomat, and his work in electricity was given a distinctly subordinate place in his life, being considered more as a recreation for his business hours than as a subject for life study. Before taking up his electrical experiments, an outline of his work along other lines will be given.

Benjamin Franklin was born in Boston, January 17, 1706, and died in Philadelphia, April 17, 1790. His family for three centuries had lived in the parish of Ecton, Northamptonshire, England, on a freehold of about thirty acres, and for several generations the head of the family had been the village blacksmith.

From the beginning of the Reformation the family had been zealous Protestants, and had incurred considerable danger in Mary's reign. They adhered to the Church of England until late in the reign of Charles II, when the persecution of the nonconformists caused the migration of many Puritans to New England. Franklin's Father, Josiah Franklin, was one of these emigrants, and landed in Boston in 1682, where he established himself in business as a soap-boiler and tallow-chandler.

He was twice married, having seven children by his first wife and ten by his second, of whom Benjamin was the youngest son. The second wife was the daughter of Peter Folger, one of the earliest settlers of New England, and zealously opposed to the persecution of the Quakers. As a child, Benjamin was so precocious that his father thought of sending him to Harvard to educate him for a minister; but the funds were too

[1] A portrait was published in Vol. VII, December, 1902. For the above sketch of the life and work of Franklin, the JOURNAL is indebted to Professor J. S. Ames, the sketch having been prepared by one of his students for one of his physical seminaries.

Digitized by Google

low, and at the age of ten, after a little more than a year in the grammar school, Franklin was set to work cutting wicks and filling molds. This work was so distasteful to him that he was seriously considering the advisability of running away to sea, when he was apprenticed to his brother James to learn the printer's trade. He was an insatiable reader, and soon became interested and proficient in his trade. He wrote many ballads and songs and hawked them about the streets.

In 1721, James Franklin began publishing the "New England Courant," the third Boston and fourth American newspaper. Franklin frequently wrote anonymous articles and smuggled them into the paper without his brother's knowledge of their authorship. Many of these attracted attention, and were attributed to prominent men of the colony. Finally, for a political article which was offensive to the legislature, James was put in jail for a month and Benjamin duly threatened. Finding himself growing unpopular in Boston, and harshly treated by his brother, whom he admits that he provoked by his sauciness, he ran away in 1723, sailing in a sloop to New York. Finding no employment there as a printer, partly on foot and partly by row boat on the Delaware, he found his way to Philadelphia, and landed there with one Dutch dollar in his pocket. He found work, and soon moved to the house of a Mr. Reed, with whose daughter, Deborah, he proceeded to fall in love. Governor Keith soon noticed his good work, and offered to help him set up in business and give him the government printing. His father declined to help him, on the ground that he was too young, but the governor advised him to go to England to get a press and useful information. He did so under the governor's promise that the ship's mail bags contained letters of introduction and credit—promises not fulfilled. He found employment as a printer, and after two years of reckless living in London, returned to Philadelphia in 1726. In 1729 he began publishing the "Pennsylvania Gazette," and in 1732, "Poor Richard's Almanac."

Before going to England, Franklin had been engaged to Miss Reed; but as he failed to write to her, she became angry and married a worthless knave, who treated her cruelly and ran away to the West Indies, where he died. Feeling himself responsible for her troubles, Franklin fell in love with her again, and married her in 1730.

Soon after his return from England he started a debating society for the "Discussion of Morals, Politics, and Natural Philosophy." This society, in 1743, developed into the American Philosophical Society.

In 1731 he founded the Philadelphia Library. In 1743 he projected the university which a few years later developed into the University of Pennsylvania.

In 1736 he was appointed clerk of the Assembly of Philadelphia; in 1737, postmaster of Philadelphia; and in 1753, Deputy Postmaster General

Digitized by Google

for the continent. Besides greatly increasing the efficiency of this department, he made it profitable.

Always interested in scientific studies, in 1742 he invented the Franklin "open stove for the better warming of rooms." While in Boston in 1746 he met a Doctor Spence, lately arrived from Scotland, and saw him perform some electrical experiments. The subject was entirely new to Franklin, and he at once became interested. The next year the Library Company of Philadelphia received from Mr. Peter Collinson, of London, a glass tube with directions for performing some electrical experiments. With this tube he began his investigations, which will be described later.

Franklin became leader of the General Assembly of Philadelphia in the controversy with the Governor during the French War, and in 1757 was sent to England to plead the cause of the assembly before the Privy Council. Before his return in 1762, he received the degree of LL. D. from Oxford and Edinburgh. His mission was successful, and on his return he received the thanks of the assembly. Two years later he was again sent to England to oppose Grenville's Stamp Act. When the Act was passed in 1765, Franklin counseled submission, and in the next ministry, that of Lord Rockingham, aided in obtaining its repeal. The next year Townsend carried his measure for taxing American imports, and Franklin was kept in England, other colonies choosing him as their representative. During his stay he made warm friendships with Burke, Lord Shelburne, Lord Howe, David Hartley, and Doctor Priestley.

Franklin's methods were conciliatory, but the independence with which he told unwelcome truths made him an object of intense dislike to the king and his friends. George III is said to have warned his ministers against the "crafty American who is more than a match for you all." Finally, in 1774, Franklin's connection with the Hutchinson affair was the occasion of an open rupture, and he was dismissed from the office of Postmaster General. About this time news of the Boston Tea Party reached England, and Franklin advised paying for the tea. Upon hearing of this, Samuel Adams remarked, "Franklin may be a good philosopher, but he is a bungling politician." Franklin remained in England a year longer to try to effect a reconciliation, but finally returned to Philadelphia in May, 1775. Next day the Pennsylvania Assembly unanimously elected him delegate to the second Congress, where he acted on the committee to draft the Declaration of Independence. He was now sent on the delicate mission to Paris, for which no other American was so well fitted. His discoveries in electricity were better known in Europe than in this country, and he was regarded by such men as D'Alembert and Diderot as the embodiment of practical wisdom. It was Turgot who said of him, "Eripuit coelo fulmen sceptumque tyrannis." He succeeded in obtaining surreptitious aid for the colonies until Burgoyne's surrender, when the Treaty of Paris was signed, almost wholly

Digitized by Google

owing to Franklin's efforts. In 1782 informal negotiations were opened by Lord Shelburne with Franklin, which finally culminated in the treaty with the colonies. He returned to America in 1785, was chosen President of Pennsylvania, and re-elected in 1786 and 1787. In 1787 he was chosen delegate to the convention which framed the constitution. He died in 1790, and was interred with his wife and daughter in the yard of Christ Church, Fifth and Arch Streets, Philadelphia. The Dictionary of American Biography says of him: "He was at once philosopher, statesman, diplomat, scientific discoverer, inventor, philanthropist, moralist and wit, while as a writer of English he was surpassed by few men of his time."

As has been already stated, Franklin's first electrical experiments were performed with a glass tube presented to the Library Association of Philadelphia in 1746, by Mr. Peter Collinson of London. His most important work was done between this time and his departure for England in 1757. His important papers take the form of letters to Mr. Collinson and to a Mr. Kinnersley, who was associated with him in his early experiments, but later moved to Boston. His letters show clearly the extreme modesty of the man. He frequently apologizes to Mr. Collinson "for taking his time for matters which, no doubt, have already been discovered by European philosophers," but says they may furnish him with some amusement. He frequently advances hypotheses without mature consideration, inviting the criticism which he has not time to make himself. He was always ready to acknowledge a mistake or ignorance of a matter, in one letter saying, "I find a frank acknowledgment of one's ignorance is not only the easiest way to get rid of a difficulty, but the likeliest way to obtain information, and therefore I practice it. I think it an honest policy. Those who affect to be thought to know everything, often remain long ignorant of many things in which others could and would instruct them, if they appeared less conceited."

Franklin's first original experiments were with fine points. In a letter dated July 11, 1747, he describes them. If a light cork ball be suspended so as to touch a charged shot, it will be repelled, but if a sharp needle be brought up within six or eight inches, the repellency is destroyed, while a blunt object must be brought to within an inch and draw a spark. If this be done in the dark, a light like that of a glow-worm appears about the point at the distance at which the repellency is destroyed. If a needle is laid on the charged shot, the cork comes back at once, showing that the point throws off, as well as draws off, the electricity, and while the needle lies on the shot, the latter can not again be charged. A more convenient electric machine was soon made, consisting of a glass sphere rotating on an axis. He soon discovered a positive and negative state of charge when he charged a man standing on wax, he himself standing on wax and rubbing the tube. Either one

Digitized by Google

could draw a spark from a person on the floor, but a stronger one from each other. From this he reasoned that electrical fire is a common element, and each of the three persons has his equal share. Some of this, however, is drawn from one and forced into the other, so that one has less than his normal quantity, or a minus amount, while the other has more, or a plus amount.

The next investigation was with Leyden jars or bottles. He found that the non-electric in bottles differs from a non-electric outside, since the electrical fire of the latter is accumulated on the surface, and forms an electrical atmosphere about the non-electric, while in the former case it is all collected in the substance of the glass. His theory of the charge was as follows: A given jar contains a normal amount of electrical fire, say twenty units. It can contain no more than this, and when a unit is put into the upper part a unit must go out of the lower part. When the jar is completely charged, there are twenty units in the upper part and an electrical vacuum in the lower. If you try to drive in more through the top, you burst the glass. You can not get any out at the top unless an equal amount can get in at the bottom. This experiment reads wonderfully like Maxwell's displacement theory. Franklin could not understand what prevented the compressed fluid in the upper part of the jar from expanding and filling the vacuum instead of having to go around the outside.

In 1748 he had analyzed his Leyden jars, and proved that the fire resided in the glass. He did this by pouring out of a charged jar the water which formed the inner conductor and putting in some fresh water, replacing the outer coating, and then discharging the jar. He distinctly states that the words charge and discharge are used only for convenience, since the amount in the jar is always the same. Otherwise a man discharging the jar would be himself charged if he stood on wax. In this year he constructed two electric motors. One was a wheel supported horizontally, with thirty radii, each having a thimble at the end. On one side was placed a jar charged through the hook, and, on the other, one charged through the coating. The wheel would revolve until the jars were discharged. The other motor was a thin glass disk, with coatings above and below. Lead bullets placed around the edge were connected alternately with the upper and lower coating, and thimbles were mounted on glass rods so as to be near the bullets as they revolved. This wheel revolved very rapidly when the two coatings were connected to charged jars, and continued in motion for an hour. Such was the power of the machine that the weight of one hundred Spanish dollars, with which it was once loaded, did not perceptibly impede its motion. He proposes to complete the work of the winter by "a picnic at which turkey is to be killed by the electrical shock and roasted by the electrical jack before a fire kindled by the electrical bottle, and the

Digitized by Google

health of the famous electricians of Europe is to be drunk in electrical bumpers under the guns of an electrical battery."

In his next letter he explains in detail his reasons for believing that lightning is an electric spark, and advances his theory, explaining the presence of the fluid in the clouds. Electricity is generated by the rubbing of an electric against a non-electrtc. The sea consists of little particles of salt rubbing against particles of water, and thus the fluid is generated. As the water evaporates, the particles carry this fluid with them to the clouds. The objections to this theory were so great, however, that he soon abandoned it. In 1750 he explained his theory of the constitution of the electric fluid, and proposed a method of testing the theory that lightning was electricity. The fluid, he thought, was an element whose particles repelled each other, and were so small that they could penetrate and permeate any substance just as water does a sponge. The particles differ from those of ordinary fire in that they can exist with water, while when water comes in contact with ordinary fire, it is evaporated, and each particle carries off a particle of the fire until it is all carried off. To test his lightning theory, he proposed to erect a sort of sentry box on some suitable tower, and extend a sharp point as far as possible into the air as a thunder cloud was passing. The electricity could then be collected and tested, as was done subsequeutly in the kite experiment. Unfortunately, there was no suitable tower available in Philadelphia. In this letter he also explains the reasons why electrics and non-electrics should be called non-conductors and conductors.

It was in December, 1750, that Franklin described an experiment which he performed accidentally. While talking to some friends, he discharged through his body two six-gallon jars which were intended for a turkey. He felt what he described as a universal blow, but saw no spark and heard no report. He concluded from this that the velocity of the discharge is greater than light, sound, or human sensation. On another occasion he received a shock through the head, but did not even feel the blow. Hence he concluded that death by electricity is painless.

In 1752, Mr. Kinnersley communicated to Franklin the discovery that a sulphur globe will give electricity different from the glass globe. Franklin verified the observation, and repeated many of his experiments for the purpose of determining which was positive and which was negative. He had great difficulty in determining, but finally decided that that from the glass was positive and that from the sulphur negative, since the former exhibits a larger, longer, more diverging and snapping brush than the negative, and appeared to be throwing off the fire. The cool breeze from the point was also stronger.

In June, 1752, Franklin carried out the famous kite experiment. The experiment had been performed a month earlier by M. Dalibard, at Marly, France, in the way originally proposed by Franklin, and to

Digitized by Google

Franklin belongs all the honor of the conception. In September, of the same year, he erected an iron rod to draw electricity down into his house, and arranged two balls to give notice when it was charged. He found that the clouds were usually charged negatively, which was what he expected. According to his theory, for a given state of a body there was a normal quantity of electricity which it would contain, just as a sponge contains a given amount of water for a given compression. Water, which was saturated as a liquid, was far below saturation when evaporated, or was charged negatively. He tried the experiment of evaporating water on a hot plate, but could find no charge on the plate or in the steam, nor could he explain why the vapor should not receive its full charge at the instant of leaving the liquid. He could not explain, either, the occasional presence of a positively charged cloud. At this time he proposed the use of lightning rods in the form of rods terminating in sharp points to draw off the electricity, and so avoid a stroke, or to conduct away the electricity if the stroke be unavoidable. The rods were erected on various houses, and effects carefully noted. For these discoveries he was awarded the Copely medal by the Royal Society in 1753.

In this year it was proposed to Franklin to measure the velocity of an electrical disturbance by connecting by a wire two springs near together, one flowing into the Potomac, the other into the Ohio, and find the time taken to go around by way of the Gulf of Mexico. Franklin explained that the current would not go that way anyway, but compared the flow to the flow of an incompressible fluid in a pipe. The moment you put more in at one end you get an overflow at the other.

In 1757 some experiments were made in Europe to find the effect of electricity on paralytic patients, and some success was reported. Patients flocked to Franklin to have the new remedy tried, and for four or five days improvements were noted, but they seemed to stop at a certain point. Franklin remarks that possibly, with a skilled physician and many slight shocks instead of the three or four heavy ones per day, cures might be effected.

In 1757 Franklin was sent to England on his first mission, and this practically brought to a close any extensive original experiments. He wrote many letters from London, and later from France, answering questions and explaining more fully his theories and the practical advantages of the lightning rod. In the little leisure time that he had, he discovered that there was no charge on the inside of a charged tin can, and made some observations on the behavior of a tourmalin when heated. He advised his friends to avoid trees during thunder-showers for two reasons: first, the tree attracts the lightning; and second, if one is in the open field, his clothing is more likely to be wet, so that if one is struck in the head, the electricity will flow off through the clothing

Digitized by Google

without harm. This hypothesis was verified on two rats; the dry one was killed, the wet one only stunned. He advised the use of electricity for killing old turkeys, as it made the flesh tender by exploding the liquid in the tissues, and so rending them. He found that a Leyden jar, hermetically sealed, would keep its charge for several months with scarcely any diminution if kept cold, but if heated, the glass allowed the passage of the current.

In one of his letters, Franklin states that he is not working to gain reputation as a philosopher, and his letters throughout show that he was actuated only by an interest in his work, and the desire to make some useful invention. His friend, Mr. Collinson, was a Fellow of the Royal Society, and succeeded in having some of Franklin's letters read. At first they were only laughed at, and were not even given a place in the Proceedings. Later, Franklin requested that they should not be published until he had time to edit them more carefully. He never found time to do this, however, and Mr. Collinson had the early papers published in London by themselves. They were translated into French, German, and Latin, and won for Franklin a high position among scientists.

Franklin wrote his own biography down to the date of his landing in London in 1757. The best edition is that of John Bigelow, Philadelphia, 1868. His works were edited by Jared Sparks, and published in ten volumes, Boston, 1850. A new edition containing material from new manuscript, was edited by John Bigelow, ten volumes, New York, 1887. There are several good lives in English, French, and German.

Digitized by Google

LETTERS TO EDITOR

DISCONTINUANCE OF CO-OPERATION IN MAGNETIC WORK WITH THE BRITISH ANTARCTIC EXPEDITION.

Previous to the departure of the "Discovery" to the Antarctic, it was arranged here by Mr. Bernacchi, in charge of the magnetographs of the "Discovery," and Dr. Farr of this observatory, with the approval of Captain Scott, that magnetograph records at quick speed should be made for twenty-four hours on the first and fifteenth of the month until the return of the Expedition. Several obsevatories undertook to co-operate in this work. Mr. Bernacchi writes that he has been able to do this so far while in winter quarters, but in consequence of his supply of fast photographic paper being insufficient, he will not be able to continue these records this winter. The co-operating observatories, Mauritius, Batavia, De Bilt, and Kew, have been advised of this and asked to discontinue likewise.

HENRY F. SKEY.
Pro Dr. C. C. FARR.

CHRISTCHURCH, NEW ZEALAND,
MAY 5, 1903.

CONTINUANCE OF INTERNATIONAL CO-OPERATION IN RAPID REGISTRATIONS DURING SPECIAL TERMS.

Although the program for international co-operation in connection with the Antarctic Expeditions, as published,[1] terminated on Feb. 15, last, it was deemed best, in the absence of official advice, by the Coast and Geodetic Survey magnetic observatories to continue the work, as outlined for the 1st and 15th of each month, a little while longer. An official inquiry was directed to the German Government through the German Embassy at Washington to which after several months a reply was received to the effect that the German Government would be glad to have the United States observatories co-operate for another year and that the work was to be timed and arranged in accordance with the program for the period February 1, 1902, to February 15, 1903.

Dr. Schmidt, in charge of the Potsdam magnetic observatory, replying to an inquiry from the Editor of the Journal briefly writes: "The Potsdam observatory on June 1st will resume the special term observations, beginning with rapid registration one-half hour before the required hour and continuing until one-half hour after the hour, hence for two hours—

[1] See T. M., Vol. VI, p. 49.

Digitized by Google

thus beginning on June 1st, rapid registration from $7^h\ 30^m$ to $9^h\ 30^m$ a. m., Greenwich mean time, June 15th, from $8^h\ 30^m$ to $10^h\ 30^m$, etc., etc. I shall continue the observations as long as it is done at other observatories."

In accordance with this advice, the Coast and Geodetic Survey is at present carrying on rapid registration work on the 1st and 15th of each month at its five observatories—Cheltenham (Maryland) Baldwin, (Kansas), Sitka (Alaska), near Honolulu (Hawiian Islands), and Vieques Island (Porto Rico).

In conclusion, I may remark from certain experiences during the past year with regard to getting necessary information promptly that international work can be conducted much more satisfactorily through individuals, or well-known committees, than through government embassies.

L. A. BAUER.

U. S. COAST AND GEODETIC SURVEY.

CONCERNING OBSERVATIONS OF TERRESTRIAL MAGNETISM AND CLOUDS CARRIED OUT AT NORWEGIAN STATIONS DURING THE YEARS 1902–1903.

The observations carried out at two of the Norwegian Northern-Light Expedition's stations, Dyrefjord in Iceland, and Bossekop in Finmark, have lately been concluded, but the work will be continued at the stations in Novaya Zemlya, and Spitzbergen, until the end of June.

Even now, by comparing the daily magnetic photograms obtained at Dyrefjord, and Bossekop, with those of earth currents from the latter, extremely interesting results have been obtained.

It was in order to solve, in the best possible manner, the problem placed before us, viz., the determination of the connection existing between terrestrial magnetic perturbations, aurora borealis, and cirrus clouds, that I, in a circular dated May, 1902,[1] took the liberty of requesting your kind assistance. In order to obtain the most complete collective views of the matter, it is necessary to procure copies of a certain number of the daily recorded photograms of magnetic variations, if possible, from all quarters of the globe.

After comparing photograms from Bossekop with corresponding ones from Potsdam, I selected thirty days, on which general magnetic disturbance was great, as those which most suited my purpose, and I have, consequently, determined to adopt these as the basis of my investigations. I now take the liberty of asking all those who are in a position to do so, to give or lend me copies—photographic preferred—of photograms of magnetic disturbances that may have occurred on those thirty days, and urge them, in the interests of science, not to mind facing the considerable amount of trouble which must be undertaken in order to fill such a

[1] See T. M. Vol. VIII.

Digitized by Google

request; and, if required, I am willing to refund any expense necessarily incurred in connection with it. In the work that I intend to publish, I shall reproduce, so far as I can by photography, a very large number of such photograms after they have been reduced to a uniform scale as regards time, so that any one may be able to check the results arrived at, by me, from my manipulation of the materials to hand.

The variations of most value for my work, are those of the two horizontal elements. In respect to the thirty days in question, when the vertical intensity shows marked variations, it will be, likewise, very important to me to obtain copies of photograms relating to vertical intensity. The thirty days I have chosen are given further on, while the Greenwich mean time of the most interesting part of the variations is likewise indicated, and I want to obtain copies of photograms comprising intervals of, at least, six to eight hours before and after this time.

5	Oct. 1902	9^h	P. M.	Greenwich Time.	13	Dec. 1902	5^h P. M. Greenwich Time.
6	— "	9^h	—	—	15	— "	1^h A. M. —
7	— "	10^h	—	—	22	— "	10^h P. M. —
8	— "	9^h	—	—	23	— "	8^h — —
11	— "	9^h	—	—	24	— "	6^h — —
25	— "	1^h	A. M.	—	26	— "	9^h — —
27	— "	7^h	P. M.	—	6	Jan. 1903	6^h — —
28	— "	8^h	—	—	12	— "	6^h — —
31	— "	1^h	A. M.	—	26	— "	10^h — —
10	Nov. "	10^h	P. M.	—	8	Feb. "	7^h — —
21	— "	9^h	—	—	10	— "	11^h — —
23	— "	11^h	—	—	15	— "	4^h — —
26	— "	4^h	—	—	1	Mar. "	11^h — —
9	Dec. "	4^h	—	—	22	— "	10^h — —
11	— "	8^h	—	—	31	— "	1^h A. M. —

In addition to such copies it would be very desirable to obtain the loan of all the photograms, taken by the observers who promised to partake in the special and rapid registrations, from the 2d to 8th December, 1902; 2d to 8th January, and 3d to 9th February, 1903. In order to be able to employ, for my purpose, the copies, and photograms referred to, it is necessary that the hours at which they were taken be stated with the greatest possible accuracy, and also the value of the base line, and that of the millimètre of the ordinates of the curves.

I also beg to request the staffs of meteorological stations at which those observations referred to in my circular of May, 1902, have been kindly effected, to now conclude the observations, and provided such has not already been done, forward me the results obtained.

I have, already, received from many stations most valuable material —and for those my thanks are due—but, as everybody will easily understand, it is necessary to obtain observations from a vast number of stations in order to gain somewhat complete general views of the matter in question.

KR. BIRKELAND.

CHRISTIANIA, JUNE, 1903.

Digitized by Google

SOME MAGNETIC OBSERVATIONS IN MEXICO.

I have the pleasure to communicate the following data that I obtained in an expedition to the northern frontier in the month of July of last year:

RESULTS.

Station.	Latitude.	Longitude W. of Gr.	Altitude.	Date.	E. Decl'n.	Incl'n.	Intensity		Total
							Hor'l.	Vert'l.	
			Meters	1902			γ	γ	γ
Chihauhua	28°38′.4	106°04′.5	1423	July 12, 13, 14	10°31′.0[1]	55°50′.6	29393	43320	52352
C. Juarez	——	——	——	July 23	——	59 21.0	——	——	——
Jimenez	27 06	104 57	——	July 27	9 57.6[2]	——	30304	——	——
Zacatecas	22 46.6	102 34.4	2443	July 29	8 57.3[3]	——	31947	——	——

In Juarez City, I did not determine D and H because of the electric railways. In Jimanez and Zacatecas, I and Z are wanting as the dip circle was somewhat injured in transportation over bad roads. All the observations were made in the field outside the cities. In my former letter I mentioned to you that the value of I that I am obtaining in Cuajimalpa is something like 20′ higher than the last that was determined here before the installation of the electric railways and which I attribute to some defect in the dip circle that I am using (Fauth, model of Kew).

M. MORENO Y ANDA.

TACUBAYA, MEXICO, JUNE 4, 1903.

[1] Between 9 and 11 a. m.

[2] Mean of observation at 8 a. m. and 2 p. m.

[3] At 10 a. m.

Digitized by Google

J. J. THOMSON.

Joseph John Thomson, D. Sc., F. R. S., Cavendish professor of experimental physics in the University of Cambridge, was born near Manchester, 18th December, 1856. He entered Owens College in that city as an engineering student in the session 1871–2. He distinguished himself in this course, but gave it up after the first two years and specialized in mathematics and physics, in which his interests had become centered. In 1876 he went to Trinity College, Cambridge, and studied for the Mathematical Tripos, becoming second wrangler and second Smith's prizeman and Fellow of Trinity in 1880. (The senior wrangler and first Smith's prizeman in that year was Professor T. Larner, the successor of the late Sir George G. Stokes in the Lucasian chair of Mathematics at Cambridge.)

In 1883 he was appointed Lecturer at Trinity and won the Adams prize in the university for his well-known "Treatise on the Motion of Vortex Rings." In the following year he was elected Fellow of the Royal Society and was appointed to the Cavendish professorship of physics, in which chair he continues so ably to maintain and extend the traditions established by his predecessors, Maxwell and Rayleigh.

One of his courses of lectures, "Applications of Dynamics to Physics and Chemistry," was published in 1886. In 1891 he prepared the third edition of Maxwell's Treatise on Electricity and Magnetism and found it necessary to write a supplementary volume to bring the work up to date. This appeared in 1892 under the title "Recent Researches in Electricity and Magnetism" and is especially noteworthy in its discussion of the discharge of electricity through gases. He continued the consideration of this latter subject in the lectures which he gave at Princeton University on the occasion of its centenary and which have since appeared in book form.

When the X-rays were discovered, he was able to bring them within the scope of Maxwell's Electro-magnetic theory and his subsequent investigations on the ionization of gases and on the nature of the cathode rays have opened up a new field of research on the ultimate relations of matter and electricity and on the phenomena of radioactivity. Numerous contributions on these fascinating subjects by himself and his pupils are to be found especially in the pages of the *Philosophical Magazine* for the last few years. In consideration of this work the Hodgkins prize of the Smithsonian Institution for the most valuable contribution to our knowledge of atmospheric air has been awarded to him this year.

He has recently developed a new theory of the arc and spark

Digitized by Google

discharge and an electrical theory of mass, which formed the subject of the Silliman lectures which he gave at Yale University in May and of a subsequent course at the Johns Hopkins University in June, of the present year. These lectures will be contained substantially in his new book which is now in the press and will appear shortly.

In 1890 he married Rose Elizabeth Paget, daughter of the late Sir George E. Paget, K. C. B. In 1894 he was President of the Cambridge Philosophical Society and in 1896, President of Section A, British Association for the Advancement of Science and since then various other honors have been bestowed upon him.

Besides the works already mentioned he has published "Elements of the Mathematical Theory of Electricity and Magnetism," 1895, and in collaboration with Professor J. H. Poynting, a "Textbook on Physics" of which two volumnes on "Sound" and "Properties of Matter" have already appeared.

Digitized by Google

NOTES

11. *The French Association for the Advancement of Science*, which meets at D'Angers from August 4–11, will discuss in the seventh section (Meteorology and Geophysics), papers relating to terrestrial magnetism, seismology, and atmospheric electricity.

12. *The Second International Seismological Conference* meets at Strasburg, from July 24–28, 1903, and will have an interesting program of subjects to discuss. Professor Harry Fielding Reid, of the Johns Hopkins University, will attend as the official delegate from the United States.

13. *The British Association for the Advancement of Science* meets at Southport, September 9–16, under the presidency of Sir Norman Lockyer. Captain E. W. Creak is chairman of Section E (Geography).

"It has been arranged that the *International Committee for Meteorology*, the members of which are representatives of official meteorological organizations in all parts of the world, shall meet at Southport during the session of the British Association. The Committee has not met in England since 1876; its last regular meeting was at St. Petersburg in 1899. The Local Committee of the British Association hope that the meeting of the International Committee at Southport may be the occasion of an increased attendance of distinguished guests at this meeting of the Association."

14. *Magnetic Survey of the Dutch Archipelago.* Dr. van Bemmelen writes that the Dutch government has granted the means for a new survey during the years 1904–1907. During each of these years the field work is to cover two to four months, only a general survey being possible with the present means. A beginning has already been made, observations having been made on the "tin island," Billiton, and at some points in the neighborhood of Batavia, and it is also hoped to secure values at different stations in Java partly to obtain early information regarding the secular variation.

On Billiton Island, van Bemmelen had the opportunity to study the magnetic effect of a natural wall of lodestone 100 m. long and 2 m. thick, and from 1–4 m. high, emerging from the top of a hill in the forest.

15. *Magnetic Work executed by the Coast and Geodetic Survey from July 1, 1902, to June 30, 1903.* The work may be summarized as follows:

Digitized by Google

A. MAGNETIC SURVEY WORK.

The magnetic elements were determined at 461 stations distributed over numerous States, 10 of the stations being in Alaska, 9 in Porto Rico, and 16 in the Philippines, Cuba, and Santo Domingo. The principal work was done in Arizona (54 stations), Florida (26), Kansas (49), Louisiana (15), Maryland (18), Michigan (14), Nebraska (19), Ohio (19), Pennsylvania (52), and Texas (72).

By December of this year, owing to the progress already made, the magnetic survey of the area bounded by latitudes 35° and 41°, and longitudes 75° and 85°, embracing the States of Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia, Ohio, North Carolina, and the eastern portions of Kentucky and Tennessee, will be completed, and the results at once submitted to a careful discussion, with the view of ascertaining what improvements, if any, are needed in the methods of work, to bring out all of the practical and scientific purposes of a magnetic survey.

The work in Louisiana was done in co-operation with the State Geological Survey.

B. OCEAN SURVEY WORK.

In January, 1903, a Lloyd-Creak dip circle was mounted on the Coast and Geodetic Survey Steamer "Blake," and observations made on the trip to Porto Rico and return. Some compass work has also been done by the other vessels of the Survey. The work has largely been of an experimental nature as yet. It has been demonstrated, however, that if the proper precautions are taken, valuable results may be secured. The Lloyd-Creak dip circle has been proved to be a most satisfactory instrument both for land and sea work.

C. MAGNETIC OBSERVATORY WORK.

The four magnetic observatories situated at Cheltenham (Maryland), Baldwin (Kansas), Sitka (Alaska), and near Honolulu (Hawaiian Islands), have been in continuous operation throughout the year. Owing to various improvements being made in the vertical-force instrument, only the first named observatory is provided with such an instrument, and, in fact, at this observatory a double set of photographic instruments are in operation (Adie pattern and Eschenhagen pattern).

In February, 1903, a temporary magnetic observatory was established in Fort Isabel, Vieques Island, Porto Rico, and since March registrations of declination and horizontal intensity have been secured.

D. SPECIAL INVESTIGATIONS.

A variety of special investigations have been made, embracing experimental work in the field and at the observatories and theoretical investigations at the office.

Digitized by Google

E. EXPEDITIONS.

Besides the work of the Survey proper, two expeditions have been fitted out with magnetic instruments, and the observers given the necessary training and furnished with the requisite data and instructions; viz., the Ziegler North Polar Expedition, W. J. Peters being in charge of the magnetic work, and the Bahama Expedition of the Baltimore Geographic Society, O. L. Fassig being in charge of the magnetic work.

F. PUBLICATIONS.

1. United States Magnetic Declination Tables for 1902, and Principal Facts Relating to the Earth's Magnetism. By L. A. Bauer, Washington, 1902.

2. The Magnetic Observatories of the United States Coast and Geodetic Survey in operation on July 1, 1902. By L. A. Bauer and J. A. Fleming. Appendix 5, Report of the Superintendent (O. H. Tittmann) of U. S. Coast and Geodetic Survey for 1902.

3. Magnetic Dip and Intensity Observations, January, 1897, to June 30, 1902, by D. L. Hazard. Appendix 6, Report of the Superintendent (O. H. Tittmann) of the Coast and Geodetic Survey for 1902.

4. Results of International Magnetic Observations made during the Total Solar Eclipse of May 18, 1901, including Results Obtained During Previous Total Solar Eclipses. By L. A. Bauer. Published in TERRESTRIAL MAGNETISM, December, 1902.

Digitized by Google

ABSTRACTS AND REVIEWS.

H. A. LORENZ'S "SICHTBARE UND UNSICHTBARE BEWEGUNGEN."[1]

This book consists of seven lectures delivered in the early part of 1901 in Holland before a popular audience. The subjects are: Rectilinear Motions, Curvilinear Motions, Vibratory Motions, and Rays of Light, Light Vibrations, Molecular Motion, Electrical Phenomena, and the Conservati n of energy.

One can not help wondering whether the subject of kinematics would draw a large audience, even in Holland. Certainly many lecturers would hesitate a long while before venturing upon such subjects as those of the first two lectures. After reading them, however, the wonder becomes how they could ever have been suspected of dryness. The beautiful logical sequence, the range of thought from molecule to fixed stars, and the novelty and aptness of illustration contribute largely to this result. The formula, $F=ma$, is, for example, applied to the case of a brass ball of 800 g. mass swinging against another ball of equal mass. The time of contact being .0002 sec., the force acting is calculated to be the weight of 600 kg.

In the second lecture, the path of a body thrown slantingly upwards is made to serve very happily as an introduction to motion in a circle. The subsequent lectures lend themselves more readily to being made interesting and thus Professor Lorentz's success is more easily won, though no less marked. The treatment of the kinetic theory of gases in the fifth lecture is especially worth reading. The reader will feel regret that the author did not distort the perspective of his treatment by amplifying the discussion of the Zeeman effect in the next and last lecture.

No doubt the loose definition of phase on page fifty-eight was a concession to the audience.

When a scientific man of Professor Lorentz's high standing takes the trouble to make some part of his knowledge clear to people in general, he deserves the thanks not alone of those to whom new vistas have thus been opened, but also of his fellow-workers, for he has helped to keep abstract science and common life in touch with each other.

To find a better example of how science ought to be popularized would be a hard task. It is to be hoped that Professor Lorentz may find time to prepare other courses of similar lectures, when he is not engaged in elaborating the theory of electrons, and that the book just received may be translated into English.

G. F. STRADLING.

NORTHEAST MANUAL-TRAINING SCHOOL, PHILADELPHIA, PA.

[1] Translated from the Dutch by G. Siebert. Vieweg und Sohn, 1902, 8°, pp. 123. Price 3 Marks.

Digitized by Google

ON THE RADIO-ACTIVITY OF GROUND AIR.[1]

Professors Elster and Geitel, having previously shown that any conductor becomes radio-active if charged negatively and exposed to the air, and that the effect is much greater when the conductor is exposed to the air in a cellar which has been kept closed, they have now made experiments to determine the source of the radio-activity in subterranean chambers. Their first thought was that possibly any mass of air would show an increase in its conductivity and radio-activity, if confined in a closed vessel, and indeed some such effect is shown by small inclosed volumes of air, but careful quantitative experiments on air contained in a large unused steam boiler showed that this could not account for the activity of cellar air. Next it was necessary to examine the material of the cellar walls and the surrounding earth. These, when tested, gave no indication of radioactivity. Finally it occurred to them to introduce a pipe 1½ meters into the earth of a garden and draw out through it air which had been contained in the ground, this air then passing into a large bell jar to be tested. One of their "loss of charge" leaf electrometers in the testing jar at once showed the remarkably high conductivity of this ground air. Furthermore, experiments with negatively charged conductors showed that this air possesses the power of imparting radioactivity in a much higher degree than even the air from cellars. The ground air loses its radioactive properties very slowly, so that it may be collected in any suitable vessels and afterwards transferred to the testing vessel containing the electrometer. In one case the conductivity of the air fell off only a fifth from the maximum in forty-eight hours. In a closed vessel the conductivity is influenced by the secondary activity imparted to the walls, so that the maximum is not attained for several hours.

Their results are most interesting when considered in connection with a paper by Professor J. J. Thomson published about the same time (Phil. Mag., Sept., 1902.) Professor Thomson discovered that air which has been bubbled through water, air into which water has been sprayed, and air which in any way has come into intimate contact with water, shows radioactive properties which are very similar to those of the cellar and ground air of Professors Elster and Geitel, so it seems probable that the activity of the ground ai ris due to the action of the ground moisture on the air as it is drawn through the soil. Tests of air drawn through small bodies of dry and moist earth should decide this point. In any case, Professors Elster and Geitel have established their conclusions that the abnormal activity of cellar air is due to the exhalation of the very active ground air from the surrounding earth, and that the ionization and radio-activity of the general body of air near the earth is to be referred to the same cause, though in the higher air strata other causes, such as the Sun's rays, may be operative. G. B. PEGRAM.

THE CONCENTRATION OF RADIO-ACTIVE EMANATIONS IN LIQUID AIR.[1]

In the spring of 1901 it was found in Professor Ebert's laboratory that when liquid air is allowed to evaporate into a vessel containing suitable means for testing the electrical conductivity of the air, no abnormal conductivity is

[1] ELSTER, J. AND GEITEL, H. Ueber die Radio-activität der im Erdboden enthaltenen Luft. Repr. from Physicalische Zeitschrift. 3. Jahrgang. No. 24. Sept. 15, 1902. 4 pp.

Digitized by Google

shown until the air has all evaporated, when suddenly the conductivity rises very much to a maximum, then undergoes a slow decrease. After carefully proving that the increase in conductivity is not due to the mere boiling of the liquid air, to any action of ice or other solid particles present therein, to any radio-active matter from the condensing apparatus, or to electrified particles present in the liquid air, the author is satisfied that the true explanation is, that the gaseous radio-active emanation, always present in small quantity in the air, is condensed at a temperature above that of liquid air, and that at the temperature of liquid air its radioactive power is latent, only coming into action again when the emanation is allowed to pass into the gaseous form. In this latter point the atmospheric emanation is different from the radium and thorium emanations, which, as Rutherford has shown, continue to decrease in activity with the time, even at temperatures many degrees below their respective points of condensation.

This conserving of the emanation at liquid air temperatures renders it possible to concentrate it very much; to do this it is only necessary to nearly evaporate successive portions of liquid air in the same vessel. Experiments were made on air from various sources: fresh air, ground air (which contains the emanation in relatively large quantity), cellar air, air that had been in intimate contact with water, and air taken in during a rain-storm. In most of the work, the air was liquefied in a condenser surrounded by liquid air under reduced pressure. A definite number of liters of the air to be tested being liquefied, the liquid was evaporated to a definite number of c.c., and the products of further evaporation passed through a system of absorption tubes (potash, chromic acid, sulphuric acid) and through a strong electric field between two coaxial cylinders (to remove any particles carrying free charges) into a glass bell jar of 60 liters capacity, which had previously contained air freshly taken in from the open. Under the bell jar was an Elster-Geitel loss-of-charge apparatus, by means of which the air conductivity before and after the introduction of the evaporated air could be measured. The loss of potential, in volts, which the charged body suffered in 15 minutes was taken as a measure of the conductivity.

With fresh air in the vessel, the loss was 11 to 17 volts, depending on atmospheric conditions, in 15 minutes. After standing, a maximum of 23 to 34 was reached in about a day, then there was a gradual decrease. 107 c.c. of freshly liquefied air evaporated under the bell jar gave during evaporation 18 to 19 until all the air was evaporated, then rose to 21 to 23 after 5 hours, 37 to 39 after 7 days; 107 c.c., remainder from the partial evaporation of 6 liters of the liquid air when allowed to evaporate under the bell jar, gave about normal conductivity values until the air was all evaporated, then rose rapidly to over 5 times the normal value, 7 hours after the evaporation. After reaching this maximum, the conductivity fell off rapidly, afterwards more and more slowly. After 100 hours it was 65 against 81 at the maximum; after 410 hours it was only 39.

Air drawn out from the ground gave similar results, except that the conductivity was in all cases far greater, the potential of the charged body

[1] H. EBERT. Ueber die Möglichkeit radio-aktiverende Emanationen in flüssigen Luft anzureichern. Repr. from Sitzungsberichte der Math.-phys.klasse der Kgl Bäyer. Akad. d. Wiss. Bd. XXXIII, 1903, Heft I; Eingelaufen 7. März.

Digitized by Google

falling in some cases at the rate of 1,000 volts in 15 minutes. By taking two equal portions of the liquefied ground air, testing one as above and keeping the other liquefied for 75 hours before testing, it was found that the radio-activity is not lost nearly as rapidly in the liquid as in the gaseous state. Indeed, it appears to be completely conserved. Curves showing the change of conductivity with time, for the air from the evaporation of liquefied ground air, are given. The walls of the vessel in which the ground air stands become slightly radioactive. Usually the rates of dissipation of + and — charges in the air are not the same, so a discussion of the probable causes of the variation in the rates is given. Experiments show that ground air is more radioactive during a period of falling barometer, doubtless because the air has come from greater depths.

Following up the work of Sella and Pocchettino and J. J. Thomson on the radio-activity of air blown through water, experiments were made on air sent over and over again through a water blast, using 8¼ liters per minute. When a certain volume of this air was sent through the drying tubes into the testing vessel, the conductivity rose to 160. If, however, this air on its way to the testing vessel had to pass through a condenser surrounded by liquid air, the conductivity was very little above the normal. When later the condenser was allowed to rise in temperature, and fresh air passed through it into the testing vessel, the conductivity again rose to 160 to 170. Thomson had previously shown that the radio-active matter in air that had been shaken up with water could not pass through a tube surrounded by a carbon dioxide ether mixture, but had not shown that the radioactive matter could be regained. A slight amount of radio-activity was detected on the walls of the vessel after this water-treated air had been standing in it. It seems probable that the radio-active matter is originally dissolved in the water, and in the water-blast process is only transferred to the air; a view which is in accord with the most recent work of Thomson on the radio-active gas present in water.

Interesting details of the experiments, references to the work of others, and pertinent suggestions are contained in the paper, which concludes with a discussion of a method for determining the essential constants of a radio-active emanation, so far as they can now be considered, from a single series of measurements on the conductivity of the air containing the emanation.

COLUMBIA UNIVERSITY, NEW YORK. GEO. B. PEGRAM.

MESSUNGEN DER ELECTRICITÄTSZERSTREUUNG IN DER FREIEN LUFT.[1]

In this paper the results of seventeen months' observations are collected and discussed with a view to ascertaining whether there is any relation between the electrical conductivity of the atmosphere and other meteorological phenomena. The discussion is wholly based upon the ion theory of conductivity.

Observations were made daily at Wolfenbüttel between 11 a. m. and

[1] J. ELSTER AND H. GEITEL. Sitzber. Kais. Acad. d. Wiss, Wien, Math.-natur. classe Bd. CXI abth. IIa, Juli, 1902, Pp. 1-36.

Digitized by Google

1 p. m., and in addition to the electrical records careful note was made of the transparency of the air and other weather conditions, and these records were amplified by referring to the records of neighboring regular meteorological stations.

The results are summarized as follows:

1. At Wolfenbüttel, with protected dispersion cylinder, the conductivity coefficient has a value of 1.33.

2. The dissipation of negative electricity is greater than of positive (Probably due to Earth's field.)

3. There is no well marked dependence, of conductivity, upon air temperatures.

4. Or upon relative humidity.

5. But conductivity does vary directly with the "saturation deficit" of water vapor in the air.

6. Impurities in the air exert a strong influence, and conductivity decreases upon the appearance of fog, smoke and dust.

7. Conductivity is greatest when the wind has a northerly component.

8. As the force of the wind increases, conductivity generally becomes greater. Squalls from N. or N. W. cause high conductivity.

9. On days with steady weather conditions, the maximum conductivity occurs about noon.

10. The annual variation shows greatest conductivity in April and least in January. L. G. SCHULTZ.

ÉTUDE DE L'ÉLECTRICITÉ ATMOSPHÉRIQUE AU SOMMET DU MONT BLANC, (4810 M) PAR BEAU TEMPÉRATURE.[1]

This paper embodies the results of an investigation which was carried on from August 31, to September 3, 1902, during a period of fair weather with southerly winds.

The records consist of:

1. The continuous registration of the diurnal variation of the electric potential at a point in air above the ground, with respect to the potential of the ground.

2. A series of direct measurements of the normal potential gradient (Volt/Meter) between two points in the air above a small horizontal snow-covered plane on the summit.

3. A series of measurements of the dissipation of positive and negative electrical charges in free air, near the ground.

The potential measurements show that: In fair weather with a south wind, near the autumnal equinox, the electrical field near the earth, on the summit of Mont Blanc, has a potential gradient of about +550 V/M; its daily curve exhibits a simple oscillation with a maximum of 700 to 1000 V/M between 3 p. m. and 4 p. m., and a minimum of 100 to 200 V/M about 3 a. m.

This confirms the general law of the variation of the Earth's field as deduced by A. B. Chauveau in his discussion of the Eiffel Tower observations.

The measurements of the dissipation of electrical charges in free air gave high values of q, as the loss of the negative charge was generally ten times as

[1] G. LE CADET. Comptes Rendus.

Digitized by Google

great as that of the positive. The q curve falls gradually to a principal minimum at 11 a. m., rises sharply to a principal maximum at 1.46 p. m., falls to a secondary minimum at 2.41 p. m., rises sharply to a secondary maximum at 3.07 p. m. and then it falls slowly to the night hours Comparitive observations were made on September 4th in a valley, under nearly the same atmospheric conditions, and the value of q was found to be about unity. These results very strongly confirm the deductions of Elster and Geitel, and they lead to the following conclusion: The apparent conductivity of the air increases with the altitude. It is sensibly the same for both signs at the bottom of valleys, but on the summit of Mont Blanc it exhibits a nearly unipolar character. The variations of the ratio q, and of the electrical field appear to be so related as to conform to the theory of the ionization of the air by solar radiation, taking into account all the meteorological conditions which may affect the mobility of the ions and the intensity of radiation.

L. G. SCHULTZ.

ÜBER ELEKTRICITÄTSZERSTREUUNG BEI NEBELIGEM WETTER.[1]

[1] A. GOCKEL. Physikalische Zeitschrift, 4 Jahrgang No. 9, S. 267–270.

During September, 1902, observations were made on the Brienzer Rothorn, at an elevation of 2300 m, for the purpose of studying the electrical phenomena due to the presence of ions in fog or cloud masses. Measurements were made of the electrical conductivity with Elster and Geitel apparatus, the electrical potential gradient, the pressure, relative humidity and temperature of the air. The electrometer readings show that the potential variations were largely dependent upon the force of the winds and the movement of fog strata. On a fair day, with but little fog, an average gradient of about 300 V/M was observed; but as night approached and fog began to form it rose to 680 V/M. During days on which the mountain was more or less enveloped by fog, the gradient ranged from 500 to 750 V/M.

The coefficient q, of the electrical conductivity of the air was found to increase regularly on a fair day. Its extreme values on September 27th, were as follows: 6 to 7 a. m., 1.31; 10 to 11 a. m., 2.81; 1 to 2 p. m., 2.02; 2 to 3 p. m., 3.38; 4 to 5 p. m., 2.41; 5.30 to 6 p. m., 4.93; 8 to 9 p. m., 1.02. The presence of mists and fogs caused great variations in the value depending upon the position and state of the fog masses. Although the author does not so state, it is evident from the context that he assumes that fog masses surrounding mountain peaks are due to strong convection currents. A fog veil suspended over the station caused q to sink to 0.79; when the station was within a fog, q was always less than with a clear sky, and if the fog was in a nascent state, q was less than unity. In quiet, lowland fogs, q was generally found to be much greater than with clear sky. These results may be explained by the theory of ions thus: In the mountain regions rapid upward air currents carry an unusual quantity of negative ions which facilitate the dissipation of a positive charge and thus tend to make $q = 1$ or less. In the lowland fogs the negative ions are laden with moisture and practically inert while the positive ions having a smaller affinity for moisture remain active and dissipate the negative charge at about the normal rate. In case of supersaturation of the water vapor of the air, the positive ions may also become nuclei for the coudensa-

Digitized by Google

tion of moisture and then q tends to equal unity. As fall and winter fogs usually occur with anticyclonic areas, the downward air currents reach the earth highly charged with positive ions from aloft, and they thus cause high potential gradients in such fogs and abnormally high values of q.

The author furthermore announces the following very important result of his investigations: During fair weather, at Freiburg, with a falling barometer and ascending air currents, positive charges are more rapidly dissipated than negative, so that the value of q becomes less than unity. This statement is indeed remarkable coming from central Switzerland where cyclonic conditions must invariably call forth föehn winds which must be highly charged with positive ions. It points out an interesting field for investigation.

The records of both Gockel and Le Cadet confirm the conclusion of the former that high values of q are less often due to an increase in the value of a_- than to a decrease in the value of $a+$, but the curves showing the diurnal variation of q on a fair day, as deduced by the two investigators are very dissimilar in that the maxima and the minima are almost exactly juxtaposed. Inasmuch as the observations were made during the same month and in the same portion of the earth it seems that there should be a better agreement.

L. G. SCHULTZ.

CHWOLSON'S LEHRBUCH DER PHYSIK.[1]

This is a German translation of the Russian edition of 1900, and will comprise four volumes. The first is on Mechanics, while the other three will contain Acoustics and Radiation, Heat, and Electricity and Magnetism.

The time has not yet come for the appearance of a text-book in which the laws of electricity will be treated as the foundation of all branches of physics, but modern tendencies already prefigure the day when the reviewer will be given the difficult task of passing judgment on such a work. Perhaps the future pioneer in this field, now at some college or "gymnasium," will win his early inspiration from the pages of the work before us. Certain it is, that Chwolson shows himself ready to leave the path of tradition, and take a step forward in the direction of presenting the facts and laws of physics in a more logical sequence and manner. Whether or not the attempt has been fully successful can only be proven when the work has been put to a practical test. As must be expected in all new departures, the volume before us contains certain defects that may impair its usefulness to some extent.

In spite of the author's assertion in the preface, the book can hardly be said to be suitable for pupils receiving their first instruction in physics. Not only is it too "advanced," but the illustrative examples used, especially in the introduction, although excellently selected, are taken freely from all branches of Physics, and hence almost unintelligible unless one has already had at least an elementary scientific training. For this reason we can not commend the idea of stating that no knowledge of mathematics beyond analytic geometry is required, and of inserting several pages on angular measurement and the principles of differential calculus. This seems especially unwise in view of

[1] *Lehrbuch der Physik* von O. D. CHWOLSON, Prof. ord. an der Kaiserl. Universität zu St. Petersburg. Erster Band. Uebersetzt von H. PFLAUM, Oberlehrer in Riga. Braunschweig, Vieweg und Sohn, 1902. Pp. XX + 791.

Digitized by Google

the fact that integral expressions are repeatedly encountered in the course of the book, which could not possibly be understood without a sound knowledge of the calculus.

The distinguishing feature of the book arises from the author's determination to treat the science as "ein einheitliches Ganzes." While a branch of physics, Mechanics is infused with the same life-giving sap that permeates the whole tree. Analogies and even numerical examples from the laws of heat, light and electricity are freely used. The order of topics, beginning with gases and ending with the laws of solid bodies is strikingly original and perfectly logical, and in general consistently developed. It is, however, somewhat astonishing to find the atom everywhere regarded as the ultimate form of matter, no mention of the existence of the electron being made. Possibly this is being reserved for the volume on electricity; but the spirit that characterizes the work should have prompted the author at least to hint at the matter. In several minor particulars, exceptions might be taken to the arrangement of material. Thus, no good reason is evident why the two chapters on gravity should be separated by a chapter on the potential theory. The discussion of the pendulum is given partly under gravity, and partly under the measurement of time.

In the introduction, a keen and interesting discussion is given of the general problems of physics, the value of hypothesis, divisions of the science, etc. We are inclined to doubt the correctness of the statement that the science of photography is based upon physics alone, since the author's definition of physics here obviously does not include Chemistry.

The second part treats of the general laws of mechanics, and trespasses upon the field usually allotted to optics to the extent of dealing with wave motion, interference, etc. It is impossible in a brief space to give a fully adequate review of this, as indeed of the whole book. Some of the proofs appear rather indirect and unsatisfactory, but on the whole the subject is treated in a masterly way.

Part III, on physical measurements, is well introduced, though more might have been said about the discarding of decimals beyond those justified by the accuracy of the observations. The descriptions of the dividing engine and the balance are particularly good, but hardly enough space seems to have been devoted to the level and the vernier. It would have been better to reserve the description of the microscope, telescope and goniometer until the subject of the lenses had been taken up. Many unnecessary instrumental details are given, but on the whole this section ought to be valuable for reference.

The sections on the properties of gases, liquids and solids are of such a uniformly high order that any criticisms are necessarily on comparatively trivial matters. The simple automatic device for raising the mercury in a Sprengel pump is unnoticed. The paragraph on vortices is decidedly inadequate, and the first definition of colloids somewhat misleading, however correct it may be historically. A brief mention is made of quartz fibers, but nothing said about their uses. These omissions are all the more conspicuous in view of the completeness of most of the work.

The book is well printed, and the diagrams and cuts of instruments are excellent. It would have been more up-to-date in appearance, had photo-

Digitized by Google

graphic reproductions been occasionally introduced, especially in illustrating capillarity, wave-motion, etc. The index is in general very satisfactory. At the end of most of the chapters a large list of references is appended; these ought to prove of great usefulness, though in some cases the most recent researches have not been included. It is to be regretted that a few of the chapters have been left without a statement of the literature.

As a text-book the work is heartily to be recommended to second or third year students of Physics, as well as to teachers. As a book of reference, it contains much that is valuable, in a more accessible form than it is to be found in the larger handbooks. We shall await with interest the appearance of the remaining volumes.

W. G. CADY.

WESLEYAN UNIVERSITY,
MIDDLETOWN, CONN.

SECOND REPORT ON MAGNETIC WORK IN MARYLAND.

BY L. A. BAUER.[1]

[Author's Abstract.]

This publication gives in detail and also summarizes all of the magnetic observations made in Maryland during the years 1896–1901, and describes the location of the stations. The observations were made with but few exceptions by the author, and the expense of the work was borne principally by the Maryland Geological Survey; though beginning with 1899, when the Division of Terrestrial Magnetism of the United States Coast and Geodetic Survey was formed, financial assistance was also rendered by the latter Survey. The instrumental outfit was loaned to the State by the Coast and Geodetic Survey.

The results are reduced to January 1, 1900, with the aid of a large number of repeat observations at the base station, Linden, Montgomery County, Maryland, from a discussion of which it was found that the average annual increase of west declination was 3′, the average annual decrease of dip was 1′.5, and the average annual decrease in horizontal intensity was 0.00007 c. g. s. units; these quantities apply, of course, only to the period of the magnetic survey. The reductions because of diurnal variation, annual variation, and disturbance variation, in the absence at that time of a magnetic observatory in close proximity to the area surveyed, had to be made with the aid of the observatory records obtained from 1889–1891, at the old and undisturbed site of the magnetic observatory which was then in operation at Washington under the auspices of the Naval observatory. For the elimination of disturbed values, use was also made of information received during the period of the survey from the Toronto magnetic observatory.

A discussion of the Linden series which embraced 22 observations of declination between July, 1896, and June, 1901, 21 values of dip between July, 1896, and July, 1900, and twenty-nine values of the horizontal intensity between July, 1896, and July, 1900, gave as the mean square error calculated from the formula,

$$\mu = \sqrt{\frac{[vv]}{n-1}}$$

in declination ± 1′.5, in dip ± 1′.17, and in horizontal intensity ± 0.00024 c. g. s. or ± $\frac{1}{88}$ H; the probable errors are, respectively, ±1′.01, ±0′.79, and ± 0.00016

[1] Special publication, Vol. V, pt. 1, Maryland Geological Survey, W. B. Clark, State Geologist. Baltimore, 1902. 98 pp. and four plates.

Digitized by Google

or $\frac{1}{1000}$ *H*. In view of the fact that these errors represent the *total* error consisting of observation error and reduction error (diurnal variation, annual variation, and disturbance variation), it must be concluded that an accuracy sufficient for all purposes of a magnetic survey was reached. Some writers, and they are generally such who either have had little or no experience in field work and in the *utilization* of the results of field work, would give the impression that almost the same degree of accuracy must be striven for in field work as in observatory work. It takes no extensive field work to very soon convince one that if the declination and dip are obtained within 2′ and the horizontal intensity to $\frac{1}{1000}$ *H*, that these are the *highest* limits that need be striven for in field work, and any attempt made other than at base stations to exceed these limits which will result in decreasing thereby the *number* of observation points, is a grievous mistake. Frequently one may content himself with a less degree of accuracy; for the irregularities in distribution of the Earth's magnetism, as invariably revealed by increasing the number of stations, far exceed, in general, the errors of observation.

The quantities given above represent, furthermore, the limit of accuracy attainable with the instrumental outfit supplied to the State. But one of the needles of the dip circle proved satisfactory, and a double set with this needle was obtained at each station. The magnetometer had wooden bars, and it was shown that the deflection distances, owing to varying conditions of moisture, changed sufficiently to produce an error of about $\frac{1}{1000}$ *H*; moreover the prescribed deflection distances of thirty-five and forty-nine cms. gave too small deflection angles for the reading power of the horizontal circle. Since the author has taken charge of the magnetic survey of the United States, he has had this outfit overhauled; new needles were supplied to the dip circle, the wooden deflection bars of the magnetometer were replaced by brass ones, and the deflection distances were reduced to thirty and forty cms.

In conformity with the author's belief that a magnetic survey should not concern itself simply with the present magnetic distribution, but should also collect all previous results, he gives some additional secular variation data obtained since the publication of the First Report.

On three maps of Maryland (scale 1 : 1,125,000 or 20 miles to the inch) are given for January 1, 1900, respectively, the true isogonic lines, the true isoclinic lines and the true lines of horizontal intensity, as drawn, as best as possible, in conformity with the actual results; the points of observation are shown by dots. The three maps unite in exhibiting a fairly uniform distribution in southern, eastern, and extreme western part of Maryland; for this portion hardly any change was required in the preliminary lines given in the First Report and dependent upon a smaller number of stations. However, in the central portion of Maryland marked irregularities exist, and for this region the preliminary iso-magnetic lines published in the First Report have suffered considerable change, owing to the multiplicity of observations. The author, furthermore, expresses his belief that even the present lines represent only approximately the actual distribution.

A most interesting center of disturbance exists near Gaithersburg, about twenty miles northwest of Washington, where is situated one of the international observatories for the determination of the variation in latitude. This site having been proposed for the location of the principal magnetic observa-

Digitized by Google

tory of the magnetic survey of the United States, it was decided to submit it first to a careful examination and so observations were made at a number of points in the vicinity. In a distance of about six miles, the declination varied from 0° 50′ W to 8° 24′ West, the dip from 71° 46′ to 70° 16′ and the horizontal intensity from 0.1880 to 0.2038. These results are exhibited in a separate map. An analysis of the forces producing the disturbances in this locality traces their source to parallel ridges running approximately in a northeast and southwest direction, and as this direction agrees with that of the serpentine beds containing magnetite, as mapped by the geologists, the inference would be that these beds, as in the northeastern part of Maryland, are the cause of the local disturbances.

The revealing of this region of disturbance emphasizes the need of careful surveys before deciding on the location of a standard magnetic observatory. The observatory was finally located in the southern part of Maryland—in the region of comparative uniform distribution (*Cf.* this volume of T. M. p. 13.)

Table XXI collects all of the results, and likewise gives the magnetic components, X, Y, and Z, and the total force W.

In conclusion, a preliminary attempt is made at an analysis of the terrestrial magnetic field in Maryland. The normal distribution is defined by a potential of simple harmonic type, the constants being determined from the observations by the method of least squares. The normal components X, Y, Z are thus not derived from independent, arbitrary formulæ as is frequently done, but are all derived from one physically interpretable function and, in consequence, refer to a common system of magnetic distribution. The publication of the final results and the discussion of the correlation of local magnetic disturbances and geological formations are deferred until the completion of the magnetic surveys of the surrounding States, now in progress.

The State of Maryland possesses now, on the average, one magnetic station to every one hundred square miles, Holland one to every forty square miles, and England one to every one hundred and thirty-nine square miles; Maryland thus ranks second in the matter of detailed magnetic surveys.

MAGNETIC OBSERVATIONS IN THE BAY OF TEPLITZ BY THE DUKE OF THE ABRUZZI NORTH POLAR EXPEDITION, 1899–1900.[1]

The observations were made by Captain Umberto Cagni, and reduced by Prof. Luigi Palazzo.

The magnetic instruments consisted of a Schneider unifilar magnetometer, and a Kew pattern dip circle. For the protection of the instruments during observation, a portable wooden house was provided. In the intervals between observations, the instruments had to be taken down, on account of the finely powdered snow which penetrated, in large quantities, even the knots and fissures of the wood.

[1] Osservazioni magnetiche eseguite dal COM TE. UMBERTO CAGNI nella Baia di Teplitz, calcolate dal PROF. LUIGI PALAZZO. Repr. from Scientific Results of the Duke of the Alruzzi Expedition, 1899–1900. (*Cf.* T. M. 189 VIII, p. 48.) Milan, 1903. 70 pp.

Digitized by Google

On account of the limited scope of the expedition, the observations had to be confined to series of absolute measurements at the same station in August, 1899, and July, 1900. However, two 24-hour series of readings were made—one of declinations, at intervals of about 15 minutes, the other of inclination at intervals of half an hour. Both elements exhibited an extreme diurnal variation of over one degree — 1° 20′ for decl., 1° 29′ for dip.

Owing to the pronounced magnetic properties of the rocks, especially of the coast moraine, the station was located near the extreme edge of a bank of ice at least 8 meters thick, which fringed the coast. Thus the observations were probably influenced only by the presence of the island as a whole, and not by any accidental distribution of the rocks.

Azimuth observations in September, 1899, and June and July, 1900, show a change of 12′ 20″, due probably to a shifting of the ice supporting the station, by the extreme pressure of the drift ice during the winter.

Great difficulty was experienced in determining the magnetic meridian with the dip circle. Owing to the small horizontal directive force of the Earth's field, a motion in alidade of 10° produced no noticeable effect on the dip needle when the circle was nearly in the prime vertical. This results in an uncertainty of about 7′ in the inclination results. A still more serious difficulty was due to the construction of the dip circle, the cross pieces of the vertical circle, and the supporting pillars completely hiding one point of the needle in some positions. Previous to the measurements in 1900, this fault was remedied by changing the position of the circle, and altering the shape of the pillars.

The Schneider magnetometer proved a much more satisfactory instrument for use in high latitudes. All the instrumental constants were carefully determined, both before and after the expedition, by Prof. Pallazo.

The following table gives the mean of the results obtained, the position of the station being: Lat., 81° 47′ 25″ N., and Long., 58° 3′ 48″ East of Greenwich.

Epoch.	East. Decl.	Incl.	Hor. Int.	Vert. Int.	Tot. Int.
1899.7	21° 10′	83° 25′.0	0.06846	0.59319	0.59713
1900.6	21° 18′	83° 01′.2	0.06855	0.55990	0.56409

UNIVERSITY OF TEXAS, AUSTIN. J. M. KUEHNE.

M. POMORTSEFF'S "ABSOLUTE DETERMINATIONS OF THE ELEMENTS OF TERRESTRIAL MAGNETISM."[1]

(THEORY, METHODS OF OBSERVATION AND COMPUTATIONS.)

The activity of the Russians in magnetic work is again shown by the publication before us. The contents are as follows:

Chapter I: (1) Fundamental laws of magnetic phenomena, (2) Magnetic poles of very short magnets, and (3) The elements of terrestrial magnetism and their determination.

[1] Published in Russian at Katherinenburg, 1900. 8°. 124 pp.

Digitized by Google

Chapter II: (1) Measurement of oscillations, (2) Measurement of force couples, and (3) Magnetic poles; influence of one magnet on another.

Chapter III: (1) Comparative determinations of the amount of the horizontal component of the force of terrestrial magnetism, (2) Absolute determinations of the amount of the horizontal component of the force of terrestrial magnetism, and (3) Continuous determinations, with formulæ for the force of terrestrial magnetism, and the introduction of corrected coefficients.

Chapter IV: (1) The determination of the magnetic inclination and declination, (2) The observation and computation of the horizontal component of the force of terrestrial magnetism, and (3) The precision with which the various elements should be determined.

Chapter V: (1) Mean values of the magnetic elements and their variations; cartographic data; brief sketch of the investigation of terrestrial magnetism, (2) Periodic measurements of the elements of terrestrial magnetism, (3) Magnetic perturbations, and (4) Distribution of the elements of terrestrial magnetism on the surface of the Earth.

U. S. C. AND G. S., WASHINGTON, D. C. W. C. HODGKINS.

ISOCLINIC AND ISOGONIC LINES IN MINDANAO ISLAND, PHILIPPINES.[1]

During the summer of 1902, Father M. S. Maso, S. J., Assistant Director of the Philippine Weather Bureau, had occasion to inspect the meteorological stations in the southern part of the archipelago, and took advantage of this trip to determine the magnetic elements at a number of places in the Island of Mindanao. From his results he was able to locate approximately the isogonic and isoclinic lines over the island for June, 1902. Both show a marked inflection toward the north, corresponding to the line of undoubted volcanic formations.

A number of the stations where Father Maso made observations had been occupied in 1888 or 1892,[2] and valuable data were thus obtained for determining the secular variation in that region. The earlier results were reduced to January 1, 1892, for use in the construction of iso-magnetic charts for that epoch. The results are given in a table, in which Father Maso has added for purposes of comparison the values of the magnetic elements at Zi-ka-wei, Hongkong, and Batavia, for the years 1892 and 1899.

From this table it is seen that the declination and horizontal intensity have been increasing throughout the island while the dip has decreased in a marked degree.

At Zamboango and Surigao observations were made also to study the diurnal variation. D. L. HAZARD.

U. S. COAST AND GEODETIC SURVEY.

[1] Isoclinic and Isogonic Lines in the Island of Mindanao. By FATHER MIGUEL SADERRA MASO, S. J., *Philippine Weather Bureau, Bulletin for October*, 1902.

[2] El Magnetismo Terrestre en Filipinos. By P. RICARDO CIRERA, S. J., Manila, 1893.

Digitized by Google

MAGNETIC OBSERVATIONS AT ZI-KA-WEI, CHINA, IN 1900.[1]

This paper gives a statement of the progress of the magnetic work at the observatory at Zi-ka-wei during the year 1900.

Photographic registrations were obtained from a declinometer, a bifilar and a balance. Absolute observations were made at intervals, and in favorable weather daily observations were made on the sun for detecting and recording the appearances of solar spots.

After some preliminary remarks relating to the sensibility of the instruments, and to a comparison of various instruments and locations made use of in making absolute observations, the main portion of the paper is devoted to a discussion of the successive changes in the values of the magnetic elements, and of the changes in their diurnal variations. In addition, a complete record is kept of all disturbances, large and small, affecting D and H, and sometimes Z; and where the amount of a disturbance is measurable its value is given in minutes of arc or in C. G. S. units, and its direction is indicated by a + or — sign. This method of recording disturbances is very neat and clear. It was explained in a review of a portion of the previous annual report of this observatory (see T. M., Vol. VII, No. 3).

Three tables give the results of the absolute observations, and a fourth table gives the monthly means of the magnetogram readings.

Taking for the first of January the mean of all the hourly values for December aud January, the annual change is indicated as follows:

	Jan. 1, 1899	Jan. 1, 1900	Difference
	° ′	° ′	′
D	2 2043 W	2 2067 W	+0.24
I	45 4715	45 4824	+1.09
H	0.32815 c. g. s.	0.32837 c. g. s.	+0.00022 c. g. s.
X	0.32788 "	0.32810 "	+0.00022 "
—Y	0.01329 "	0.01343 "	+0.00004 "
Z	0.33729 "	0.33771 "	+0.00042 "
XW	0.47058 "	0.47103 "	+0.00045 "

The report does not make mention of any particularly interesting or important manifestation during the year. WM. F. WALLIS.

U. S. COAST AND GEODETIC SURVEY.

[1] Bulletin Mensuel de l'Observatoire Magnétique et Météorologique de Zi-ka-wei, Chine; tome XXVI, année 1900. Changhai, 1902.

Digitized by Google

Digitized by Google

ART
TILDEN FOUNDATIONS

Digitized by Google

Stephen Joseph Perry.

Digitized by Google

THE NEW
PUBLIC LIB
ASTOR, LEN
TILDEN FOUNDATI

Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME VIII SEPTEMBER, 1903 NUMBER 3

THE PHYSICAL DECOMPOSITION OF THE EARTH'S PERMANENT MAGNETIC FIELD.[1] No. III.

a. The Earth's Total Magnetic Energy.
b. The Seat of the Principal Cause of the Secular Variation.
c. On the Improvement of the Gaussian Theory.

By L. A. Bauer,

Lecturer in Terrestrial Magnetism, Johns Hopkins University; Chief of Division of Terrestrial Magnetism, U. S. Coast and Geodetic Survey.

a. THE EARTH'S TOTAL MAGNETIC ENERGY.[2]

The purpose of this paper is to determine wether the accumulation of magnetic data is already sufficient to ascertain if the total magnetic energy of the Earth's so-called "permanent" magnetic field has remained constant for the period of the accumulated data, or has been subject to a secular variation, as in the case of all the magnetic elements. A secular variation of the magnetic elements may result from: (a) secular changes in the direction or directions of magnetization of the Earth; (b) secular changes in the intensity of magnetization of the Earth, and (c) from operation of both causes (a) and (b). From previous investigations of the secular variation, cause (a) appeared to me the predominant factor.

[1] For No. I of these researches, see this Journal. Vol. IV, 1899, p. 35, and for No. II, see Vol. VI, 1901, p. 13.

[2] Presented, in abstract, for the author, by Professor A. Schuster, before Sec. A of the British Association for the Advancement of Science, Sept., 1903.

Digitized by Google

The expression to be established, defining what I term the "Earth's total magnetic energy" is independent of the *directions* of the magnetization of the Earth, and hence should remain constant for all time, if the secular variations be due solely to cause (a). If, however, the values of the magnetic energy for two periods, separated by a suitable interval, differ by an amount which can not be accounted for by uncertainties in the values themselves, arising from inadequacy of the data or from imperfections in the method of calculation, then we shall have evidence of great importance to theories of the Earth's magnetism, viz: that the Earth's intensity of magnetization, owing to some cause, is subject to secular change. And if so, it is very important to know whether the Earth's magnetic energy is increasing or decreasing. Manifestly, therefore, the present investigation is one well worth our attention, whatever the outcome may be, even though it may but lead to the conclusion that our present knowledge of the actual distribution of the Earth's magnetism, in spite of the extensive data already accumulated, is in reality a very unsatisfactory one.

How are we to define the "Earth's total magnetic energy"?

The potential of the Earth's total magnetism can be expressed, with great approximation, as Gauss first showed, in solid spherical harmonics to terms of the fourth order inclusive; the addition of terms of the fifth and sixth order, as revealed by the investigations of Adams, Fritsche, and Schmidt effect some improvement. I have shown in my previous papers, that the spherical harmonic of the first order can be physically interpreted as arising from a homogeneous magnetization of the Earth about a diameter inclined to the axis of rotation;[1] the inclination of this axis is about $11.^{\circ}4$, and this first harmonic term represents, approximately, $\frac{7}{10}$ of the Earth's total magnetization. The well-known expression of the "Earth's magnetic moment," as introduced by Gauss, represents only that portion of the total magnetization which arises from the first term, *i. e.*, from the homogeneous magnetization. Now, if we tabulate all the values of the magnetic moment obtained thus far by the various computers of the Gaussian potential, whose detailed results will be found given in a subsequent table, it would appear as though the magnetic moment has suffered a perceptible diminution—1.6%—during the period 1838–1884.

[1] I have recently found that I was anticipated in this interpretation of the first harmonic by Professor J. D. EVERETT, in his "Units and Physical Constants." London. Macmillan & Co., 1879, p. 125, paragraph 151.

Digitized by Google

VALUES OF THE EARTH'S MAGNETIC MOMENT IN C. G. S. UNITS.

No.	Computer of Potential.	Epoch.	Value.	
1	Erman-Petersen	1829	0.32690 R^3	
2	Adams	1842.5	32820	Mean 1, 2 & 3, 1838, 0.32812 R^3
3	Fritsche	1842.5	32927	4, 5, 6 & 7, 1884, 32288
4	Adams	1880	32344	
5	Fritsche	1885	32272	Change in 46 years, 0.00524 R^3
6	Neumayer-Petersen . .	1885	32237	Hence, 1.6%
7	Schmidt	1885	32298	

Since the quotient of the magnetic moment by the Earth's total volume, represents the intensity of magnetization per unit of volume, the conclusion would, therefore, apparently be that the intensity has decreased at an alarming rate in forty-six years. The same conclusion would be reached with regard to the Earth's magnetic energy, since the latter, for the homogeneous magnetization portion, can be expressed in terms of the magnetic moment.

The question arises: Is this comparatively great loss in the magnetic moment during an interval of but half a century, to be ascribed to insufficiency or imperfection of data for the periods for which the calculations are made, or, if we were to take into account the remaining portion of the Earth's magnetization, represented by the second, third, and fourth harmonics, would the loss of energy of the first term be compensated for, wholly or partially, by a possible gain in energy of the remaining terms, or would the remaining terms likewise exhibit a decrease in energy?

To answer these questions, I shall introduce the well-known function in physics, expressing the energy of a distribution of forces in terms of the field, and I shall designate it by the letter W, the initial letter of "work" or the German "werk."[1]

It is defined as the sum total of the magnetic energy of all the elements of volume in the space bounded by the Earth's surface and a sphere of infinite radius, *i. e.*, of radius large enough that the energy of the excluded portion may be neglected,[2] as due to the field of force arising from the Earth's magnetization. The magnetic energy of an element of volume in a field of force of the kind

[1] The Earth's total potential is not used for these investigations, as the integral of this potential for any closed space is zero for every period, just as the Earth's total quantity of magnetism is supposed always zero.

[2] At a height above the Earth, fifteen times that of the Earth's radius, or about one-fourth the distance to the Moon, the Earth's total magnetic force will have dwindled to a quantity equal to the error of observation of the best-class instruments used in making field observations of the magnetic elements.

293713

Digitized by Google

here discussed, may be taken as proportional to the square of the force of the field at the point considered; it represents the amount of work done to bring, for example, a unit magnetic pole repelled by the field from an infinite distance to the point. The factor of proportionality μ, is the inductivity or the magnetic permeability of the medium; for the space regarded we may take this, I presume, as uniform, and set it equal to unity. Were the portion of space occupied by the Earth itself, also embraced, then μ could no longer be regarded as uniform. Owing to our ignorance of the precise composition of the Earth's interior, the law of variation of μ is not known, and there would, hence, result expressions in the integral, representing W, which could not be evaluated. *W has, therefore, been confined to the space outside.*

It is, doubtless, unnecessary to remark that the magnetic energy of any element of volume, outside the Earth, due to fields giving rise to periodic or non-periodic magnetic variations, *e. g.*, the diurnal variation, magnetic storms, etc., is not here considered, since in the field of force, usually referred to as the "permanent or quasi-permanent field," all variations at any particular time are supposed eliminated.

The mathematical expression for the energy of a field of force obeying Newton's law, as will be found from various text-books,[1] is:

$$W = \frac{1}{8\pi} \int \mu F^2 \, d\tau \quad . \qquad (1)$$

μ = magnetic permeability at any point in space; F = the total field intensity at any point, x, y, z; $d\tau = dx\, dy\, dz$ = element of volume.

Confining the integral to the space outside of the Earth, μ will be regarded, as already stated, constant and set equal to unity. Introducing the polar co-ordinates, r (radius vector), u (co-latitude), and λ (the longitude counted positive to the eastward), and letting X, be the component directed positive to the north, Y, the component directed positive to the east, and Z, the component, directed positive downwards (towards nadir), and if R be the Earth's mean radius we have:

$$W = \frac{1}{8\pi} \int_0^{2\pi} \int_0^{\pi} \int_R^{\infty} (X^2 + Y^2 + Z^2)\, r^2 \sin u \, d\lambda \, du \, dr \quad . \qquad (2)$$

In this equation, as in all subsequent ones, r is supposed counted positive outwards from the center of the Earth.

[1] An admirable work for American students, is: WEBSTER'S Electricity and Magnetism. Macmillan & Co. 1897.

Digitized by Google

If V be the magnetic potential at any point in the external space, then

$$X = -\frac{\partial V}{\partial x} \quad , \quad Y = -\frac{\partial V}{\partial y} \text{ and } Z = -\frac{\partial V}{\partial z} \quad .$$

Substituting in equation (2), applying Green's theorem to the right hand member, and remembering that for the space considered, $\Delta V = 0$, in accordance with Laplace's equation[1] and also that both V and Z vanish for $r = \infty$, we obtain as another expression for the energy:

$$W = -\frac{R^2}{8\pi} \int_0^{2\pi} \int_0^{\pi} V Z \sin u \, d\lambda \, du \quad . \tag{3}$$

This integral, as the one in (2), is positive, since, in accordance with the notation used in this paper, V and Z are, at every point of opposite sign.

Substituting the dimensions of field intensity and of potential in equation (2) or (3), it will be found that W has correctly the dimensions of energy or work, $[M L^2 T^{-2} \cdot]$

The Earth's total magnetic energy can thus be calculated in two ways:

1. By obtaining the sum total of the products of the square of the total intensity of the field into the element of volume, at every point in the entire space outside the Earth, and dividing the sum by 8π.

2. By obtaining the sum total of the products of the magnetic potential and the vertical component of the field intensity into the element of surface, for the entire surface of the Earth, and dividing the sum by 8π.

First Method of Computing the Earth's Magnetic Energy.

We must know the magnetic potential V at every point for the space considered. Following the notation as already used in Nos. I and II of these researches,[2] which is the same as that adopted by Schmidt, we have:

$$X = \frac{1}{r} \cdot \frac{\partial V}{\partial u} \quad , \quad Y = -\frac{1}{r \sin u} \cdot \frac{\partial V}{\partial \lambda} \text{ and } Z = \frac{\partial V}{\partial r} \quad . \tag{4}$$

[1] $\Delta V = 0$, is also the condition that W shall have a minimum value for the space considered.

[2] In No. I, p. 38, equation (2) should read

$$X = +\frac{1}{R} \frac{\partial V}{\partial u} \quad .$$

Digitized by Google

$F^2 = X^2 + Y^2 + Z^2$ is then known at every point, and the integrations are easily effected.

The potential at any point in the space considered, due to a magnetic system inside the Earth, may be expressed as follows:

$$V = \frac{R^3}{r^2} \cdot P_1 + \frac{R^4}{r^3} \cdot P_2 + \frac{R^5}{r^4} \cdot P_3 + \ldots \qquad (5)$$

$P_1, P_2, P_3, \ldots$ are, respectively, surface spherical harmonics of 1st, 2d, 3d, and etc., orders.

For example, $P_1 = [g_{10} \cos u + (g_{11} \cos \lambda + h_{11} \sin \lambda) \sin u]$.

$$X = \frac{R^3}{r^3}\left(\frac{\partial P_1}{\partial u} + \ldots\right), \quad Y = -\frac{1}{\sin u} \cdot \frac{R^3}{r^3}\left(\frac{\partial P_1}{\partial \lambda} + \ldots\right),$$

$$\text{and } Z = -\frac{R^3}{r^3}\left(2 P_1 + 3 \frac{R}{r} \cdot P_2 + 4 \frac{R^2}{r^2} \cdot P_3 + \ldots\right). \qquad (6)$$

As the expression W will contain the squares of the Gaussian coefficients (the g's and h's), I shall employ entirely subscripts to designate the coefficients of the various terms, and for convenience in writing and printing, omit furthermore the commas between the subscripts. The g's and h's, of which the collective number is 24 for terms to the fourth order, are coefficients determined for any particular period from the known values X and Y and Z.[1]

The values of g and h as obtained by various computers of the Earth's magnetic potential, are given later.

Forming the quantity $X^2 + Y^2 + Z^2$, omitting at once terms which by well-known formulæ in integral calculus, or in spherical harmonics, are known to vanish when integrated over the entire Earth,[2] and performing the various integrations we have:

$$\left.\begin{aligned} W &= W_1 + W_2 + W_3 + W_4 + \ldots. \\ &= R^6 \Big\{ \tfrac{1}{3}(g_{10}^2 + g_{11}^2 + h_{11}^2) + \tfrac{1}{5}\big[\tfrac{1}{3} g_{20}^2 + \tfrac{1}{2}(g_{21}^2 + h_{21}^2) \\ &\qquad + 2(g_{22}^2 + h_{22}^2)\big] \\ &\quad + \tfrac{1}{35}\big[\tfrac{8}{5} g_{30}^2 + \tfrac{16}{15}(g_{31}^2 + h_{31}^2) + \tfrac{8}{3}(g_{32}^2 + h_{32}^2) + 16(g_{33}^2 + h_{33}^2)\big] \\ &\quad + \tfrac{1}{63}\big[\tfrac{32}{35} g_{40}^2 + \tfrac{4}{7}(g_{41}^2 + h_{41}^2) + \tfrac{5}{7}(g_{42}^2 + h_{42}^2) + 4(g_{43}^2 + h_{43}^2) \\ &\qquad + 32(g_{44}^2 + h_{44}^2)\big] + \ldots. \Big\} \end{aligned}\right\} \qquad (7)$$

[1] Like the magnetic elements, the coefficients are subject to a secular variation, and presumably, in accordance with the same law as applies to the elements themselves. Thus, since the secular variation investigations of the observed elements show that for an interval of a century or more the variation can be expressed in the form of a Bessel series, of which the first sine term represents a very close approximation, we may expect that the first approximation to the law of secular variation of the Gaussian coefficients is also that of a simple sine function of the element t, time.

[2] Thus, for example, it can be shown that only terms involving the squares of the individual coefficients to contribute to W, all the product terms disappearing when integrated over the entire surface.

Digitized by Google

Second Method of Computing the Earth's Magnetic Energy.

Substituting the values of V and Z in equation (3), and omitting all products of the spherical harmonic terms, which when integrated over the entire Earth's surface are known to vanish, in accordance with well-known theorems in spherical harmonics, we have:

$$W = \frac{R^6}{8\pi} \int_0^{2\pi} \int_0^{\pi} (2 P_1^2 + 3 P_2^2 + 4 P_3^2 + - - -) \sin u \, d\lambda \, du \quad . \quad (8)$$

This is a decidedly simpler expression than the one from the first method; it was found to lead to the same result as already given, and thus equation (7) was checked.

With the aid of Schmidt's "R" functions, which, to avoid confusion with R, the Earth's mean radius, I shall designate by "S," and which are equal to the P functions multiplied by a factor "s," determined so that:

$$\int_0^{2\pi} \int_0^{\pi} (S^2 = s^2 P^2) \cos^2 m\lambda \text{ (or } \sin^2 m\lambda) \sin u \, d\lambda \, du = 4\pi \quad ,$$

the expression for W can be put in its most elegant form.

Instead of the g and h coefficients of Gauss, we shall now have the γ and η coefficients of Schmidt, the two sets of coefficients being related thus:

$$s_{nm} \cdot \gamma_{nm} = g_{nm} \quad , \quad s_{nm} \cdot \eta_{nm} = h_{nm} \quad .$$

The values of s_{nm} are given later. Continuing, we have as our final expression:

$$W = R^8 [(\gamma_{10}^2 + \gamma_{11}^2 + \eta_{11}^2) + \tfrac{1}{3}(\gamma_{20}^2 + \gamma_{21}^2 + \eta_{21}^2 + \gamma_{22}^2 + \eta_{22}^2) + 2(\gamma_{30}^2 + \gamma_{31}^2 + \eta_{31}^2 + \gamma_{32}^2 + \eta_{32}^2 + \gamma_{33}^2 + \eta_{33}^2) + \tfrac{1}{5}(\gamma_{40}^2 + \gamma_{41}^2 + \eta_{41}^2 + \gamma_{42}^2 + \eta_{42}^2 + \gamma_{43}^2 + \eta_{43}^2 + \gamma_{44}^2 + \eta_{44}^2) + \ldots] \quad . \quad (9)$$

I have made independent computations, using both formulæ (7) and (9), getting identical results, and have thus checked the correctness of these two formulæ.

Table II gives a tabulation of the Gaussian coefficients as obtained by various computers for various epochs. The references to the publications from which the figures were taken are appended. The figures in column 10 have been obtained from those in column 13, by multiplying by the conversion factor, as given in Table I. It should be noted that the signs in Table II, in conformity with the

Digitized by Google

notation used by Schmidt and myself, are the reverse of those given by the computers who followed Gauss's notation. Strictly speaking it is not quite correct, because of the greatly varying magnitudes of the P coefficients, as was first pointed out by Schmidt, to express all the g's and h's to the same decimal; their relative importance can not always be gauged by their magnitudes. In this respect the coefficients introduced by Schmidt, and as given in Table III, have a decided advantage.

Columns 1 to 5 inclusive, and 11 and 12, give the values of the coefficients, concluding the harmonic series with terms of the fourth order, whereas columns 6–10 and 13 give the results with terms of the fifth and sixth order included. The effect on the coefficients, resulting from extension of the series, can thus be seen by comparing the respective columns.

The results from the potential computation of Quintus Icilius for 1880, are too defective to warrant including them in the table, and have accordingly, been omitted.

Column 14 gives the coefficients for the small external potential deduced by Schmidt for 1885, and 15, the same, as deduced by Fritsche from the combined results for 1842 and 1885.

TABLE I. FACTORS FOR CONVERTING SCHMIDT'S COEFFICIENTS INTO GAUSSIAN COEFFICIENTS.

	Factor	Logarithm		Factor	Logarithm		Factor	Logarithm		Factor	Logarithm
S_{00}	1	0.00000	S_{30}	$\frac{5}{2}\sqrt{7}$	0.82049	S_{50}	$\frac{63}{8}\sqrt{11}$	1.41695	S_{60}	$\frac{231}{16}\sqrt{13}$	1.71646
S_{10}	$\sqrt{3}$	0.23856	S_{31}	$\frac{5}{4}\sqrt{42}$	0.90853	S_{51}	$\frac{21}{8}\sqrt{165}$	1.52787	S_{61}	$\frac{33}{8}\sqrt{273}$	1.83351
S_{11}	$\sqrt{3}$	0.23856	S_{32}	$\frac{1}{2}\sqrt{105}$	0.70956	S_{52}	$\frac{3}{4}\sqrt{1155}$	1.40635	S_{62}	$\frac{33}{8}\sqrt{2730}$	1.73145
S_{20}	$\frac{3}{2}\sqrt{5}$	0.52558	S_{33}	$\frac{1}{4}\sqrt{70}$	0.32049	S_{53}	$\frac{9}{16}\sqrt{770}$	1.19337	S_{63}	$\frac{11}{16}\sqrt{2730}$	1.55535
S_{21}	$\sqrt{15}$	0.58805	S_{40}	$\frac{105}{8}$	1.11810	S_{54}	$\frac{21}{8}\sqrt{385}$	0.86676	S_{64}	$\frac{231}{16}\sqrt{91}$	1.29391
S_{22}	$\frac{1}{2}\sqrt{15}$	0.28702	S_{41}	$\frac{21}{4}\sqrt{10}$	1.22016	S_{55}	$\frac{3}{16}\sqrt{154}$	0.36676	S_{65}	$\frac{3}{16}\sqrt{2002}$	0.92373
			S_{42}	$\frac{21}{4}\sqrt{5}$	1.06964				S_{66}	$\frac{1}{32}\sqrt{6006}$	0.38414
			S_{43}	$\frac{3}{4}\sqrt{70}$	0.79761						
			S_{44}	$\frac{21}{8}\sqrt{35}$	0.34607						

With the aid of the figures in Tables I and II, we can now compute the magnetic energy. To show the effect of the various terms, the following specimen, using formula (9) is given.

Digitized by Google

TABLE II. Values of the Gaussian Coefficients, in units of the fifth decimal.

	1. Er.-Pet. 1829	2. Gauss 1830	3. Adams 1840–5	4. Adams 1880	5. Neu.-Pet 1885	6. Adams 1840–5	7. Fritsche 1840–5	8. Adams 1880	9. Fritsche 1885	10. Schmidt 1885
g_{10}	− 32007	− 32348	− 32173	− 31611	− 31572	− 32187	− 32271	− 31684	− 31635	− 31733
g_{11}	− 2835	− 3111	− 2833	− 2470	− 2481	− 2778	− 2751	− 2427	− 2414	− 2356
h_{11}	+ 6011	+ 6246	+ 5820	+ 6071	+ 6026	+ 5783	+ 5931	+ 6030	+ 5914	+ 5984
g_{20}	− 121	+ 771	+ 57	− 749	− 791	+ 127	+ 28	− 731	− 526	− 785
g_{21}	+ 4454	+ 5064	+ 4887	+ 5078	+ 4980	+ 4913	+ 4746	+ 5136	+ 4962	+ 4895
h_{21}	− 72	+ 211	− 194	− 1299	− 1300	− 181	− 245	− 1293	− 1307	− 1243
g_{22}	− 125	− 17	+ 38	+ 532	+ 567	+ 35	+ 66	+ 530	+ 589	+ 587
h_{22}	+ 1264	+ 1363	+ 1174	+ 1287	+ 1260	+ 1165	+ 1148	+ 1289	+ 1230	+ 1294
g_{30}	+ 1876	+ 659	+ 2448	+ 2856	+ 2436	+ 2416	+ 2148	+ 2680	+ 2556	+ 2342
g_{31}	− 2986	− 4296	− 3366	− 4383	− 3956	− 3130	− 3362	− 4197	− 3807	− 3775
h_{31}	− 1645	− 1670	− 1213	− 573	− 738	− 1372	− 1263	− 748	− 1005	− 907
g_{32}	+ 3073	+ 2558	+ 2769	+ 2793	+ 2786	+ 2802	+ 2660	+ 2822	+ 2667	+ 2767
h_{32}	+ 621	+ 796	+ 408	− 36	+ 44	+ 409	+ 400	− 40	− 13	+ 51
g_{33}	+ 127	− 49	+ 207	+ 289	+ 327	+ 207	+ 189	+ 289	+ 368	+ 316
h_{33}	+ 725	+ 655	+ 678	+ 493	+ 549	+ 678	+ 699	+ 493	+ 555	+ 540
g_{40}	+ 2738	+ 3804	+ 2909	+ 3223	+ 3440	+ 3105	+ 2944	+ 3375	+ 4014	+ 3478
g_{41}	+ 3840	+ 5329	+ 3183	+ 3461	+ 3060	+ 3286	+ 3426	+ 3683	+ 3104	+ 2839
h_{41}	+ 320	− 2240	+ 498	+ 1038	+ 1188	+ 551	+ 541	+ 1062	+ 1381	+ 1567
g_{42}	+ 1559	+ 1600	+ 1557	+ 1949	+ 1975	+ 1528	+ 1647	+ 1933	+ 2128	+ 2019
h_{42}	− 1085	− 1488	− 996	− 539	− 715	− 989	− 956	− 522	− 652	− 669
g_{43}	− 671	− 691	− 352	− 557	− 684	− 353	− 304	− 559	− 601	− 646
h_{43}	− 301	+ 6	− 391	− 432	− 512	− 391	− 429	− 433	− 525	− 471
g_{44}	− 90	+ 144	− 14	+ 108	+ 85	− 14	− 000	+ 108	+ 63	+ 118
h_{44}	− 111	− 111	− 101	− 94	− 97	− 100	− 103	− 94	− 103	− 55
g_{50}						− 237	− 183	− 1290	− 1208	− 1332
g_{51}						+ 3617	+ 3623	+ 2841	+ 3028	+ 4013
h_{51}						− 2440	− 2312	− 2680	− 3647	− 2731
g_{52}						+ 3049	+ 2942	+ 2684	+ 1961	+ 2192
h_{52}						+ 116	+ 293	− 297	− 227	− 255
g_{53}						+ 108	+ 38	+ 55	+ 272	+ 78
h_{53}						− 44	− 193	− 131	+ 49	+ 109
g_{54}						− 125	− 109	− 20	− 134	− 15
h_{54}						− 83	− 142	− 115	− 132	− 169
g_{55}						+ 70	+ 76	+ 66	+ 64	
h_{55}						+ 40	+ 42	+ 19	+ 43	
g_{60}						+ 1384	+ 313	+ 364	+ 1285	+ 312
g_{61}						+ 1256	+ 1153	+ 2724	+ 1686	+ 409
h_{61}						+ 644	+ 389	+ 284	+ 1796	+ 1704
g_{62}						− 1293	− 1088	− 731	− 572	− 808
h_{62}						+ 320	+ 293	+ 824	+ 1122	+ 970
g_{63}						− 1114	− 1411	− 1723	− 1502	− 1616
h_{63}						− 572	− 522	− 528	− 757	− 647
g_{64}						− 298	− 191	− 354	− 200	− 118
h_{64}							− 279	− 127	− 184	− 346

TABLE III. Values of Schmidt's Coefficients, in units of the fifth decimal.

	11. Neu-Pet. 1885	12. Schmidt 1885	13. Schmidt 1885	14. V e S. 1885	15. V e F'42-'85
γ_{10}	−18228	−18243	−18321	−107	−137
γ_{11}	− 1433	− 1471	− 1361	+139	+ 40
η_{11}	+ 3479	+ 3496	+ 3455	− 2	+ 22
γ_{20}	− 236	− 243	− 234	+ 1	− 28
γ_{21}	+ 1286	+ 1267	+ 1264	− 32	− 13
η_{21}	− 336	− 340	− 321	+ 4	+ 7
γ_{22}	+ 293	+ 300	+ 303	− 28	− 12
η_{22}	+ 651	+ 653	+ 668	+ 2	− 32
γ_{30}	+ 368	+ 405	+ 354	0	− 15
γ_{31}	− 488	− 538	− 466	+ 14	+ 41
η_{31}	− 91	− 57	− 112	− 0	+ 25
γ_{32}	+ 544	+ 527	+ 540	− 14	− 34
η_{32}	+ 9	+ 8	+ 10	− 5	+ 9
γ_{33}	+ 156	+ 155	+ 151	+ 6	− 14
η_{33}	+ 263	+ 263	+ 258	− 21	− 18
γ_{40}	+ 262	+ 259	+ 265	+ 12	− 8
γ_{41}	+ 184	+ 158	+ 171	− 14	− 20
η_{41}	+ 72	+ 68	+ 94	− 3	− 7
γ_{42}	+ 168	+ 172	+ 172	+ 15	+ 14
η_{42}	− 61	− 63	− 57	+ 19	+ 11
γ_{43}	− 109	− 106	− 103	+ 1	− 4
η_{43}	− 82	− 79	− 75	+ 14	+ 15
γ_{44}	+ 38	+ 40	+ 53	+ 18	+ 14
η_{44}	− 44	− 42	− 25	− 2	− 3
γ_{50}			− 51	− 2	− 22
γ_{51}			+ 119	+ 21	+ 25
η_{51}			− 81	+ 6	+ 1
γ_{52}			+ 86	+ 21	+ 6
η_{52}			− 10	+ 7	+ 3
γ_{53}			+ 5	− 0	+ 1
η_{53}			+ 7	− 9	− 8
γ_{54}			− 2	− 20	− 2
η_{54}			− 23	− 4	− 5
γ_{55}					− 9
η_{55}					− 3
γ_{60}			+ 6	+ 0	+ 6
γ_{61}			+ 6	− 16	+ 5
η_{61}			+ 25	− 5	+ 6
γ_{62}			− 15	+ 11	+ 6
η_{62}			+ 18	+ 8	− 6
γ_{63}			− 45	+ 19	+ 2
η_{63}			− 18	+ 10	+ 5
γ_{64}			− 6	+ 16	− 2
η_{64}			− 7	+ 25	− 3

Digitized by Google

TABLE IV. Specimen of calculation of $\frac{W}{R^3}$.

		11. Neu.-Pet. 1885	12. Schmidt 1885	13. Schmidt 1885			11. Neu.-Pet. 1885	12. Schmidt 1885	13. Schmidt 1885
2nd	γ^2_{10}	0.033226	0·033281	0·033566	3rd	γ^2_{20}	.000009	.000009	.000008
	γ^2_{11}	205	216	185		γ^2_{21}	248	241	240
	η^2_{11}	1210	1222	1194		η^2_{21}	16	18	15
I		.034641	34719	34945		γ^2_{22}	13	14	14
						η^2_{22}	63	64	67
					II		349	346	344
4th	γ^2_{30}	28	33	25	5th	γ^2_{40}	18	17	18
	γ^2_{31}	48	58	43		γ^2_{41}	8	6	7
	η^2_{31}	1	1	3		η^2_{41}	2	1	2
	γ^2_{32}	59	56	58		γ^2_{42}	8	7	7
	η^2_{32}	0	0	0		η^2_{42}	1	1	1
	γ^2_{33}	5	5	5		γ^2_{43}	2	3	3
	η^2_{33}	14	14	13		η^2_{43}	2	2	1
III		155	167	147		γ^2_{44}	0	0	1
						η^2_{44}	0	0	0
					IV		41	37	40
II + III + IV,		.000545	.000550	.000531					
Total, ...		.035186	.035269	.035476					

TABLE V. VALUES OF THE EARTH'S TOTAL MAGNETIC ENERGY.

[The tabular numbers are to be multiplied by the cube of the Earth's mean radius.]

No.	Computer of Potential	Epoch	I	II	III	IV	II + III + IV	Total
1	Erman-Petersen .	1829	.03562	.00026	.00015	.00004	.00045	.03607
3 and 6	Adams . .	1842.5	3590	29	15	3	47	3637
4	Fritsche . . .	1842.5	3614	28	14	3	45	3659
8	Adams . . .	1880	3481	36	17	4	57	3538
9	Fritsche . . .	1885	3472	34	15	4	53	3525
5 and 11	Neumayer Petersen .	1885	3464	35	16	4	55	3519
10 and 13	Schmidt . .	1885	3494	34	15	4	53	3548
	Mean of first three . . .	1838	.03589				·00046	·03635
	Mean of last four	1884	3478				54	3532
	Change in . .	46 years	—.00111				+·00008	—·00103

Digitized by Google

Table V, giving the values of the Earth's total magnetic energy, will be readily understood; thus, for 1829, the energy from the first harmonic is 0.03562 R^3; from the second, 0.00026 R^3; from the third, 0.00015 R^3, from the fourth, 0.00004 R^3, the total of the four terms being 0.03607 R^3. The results from the Gaussian computation are omitted, as it was not deemed fair to Gauss to present his results—preliminary, as he desired them considered--alongside of those dependent upon superior material.

A close scrutiny of the material and method of computation, employed by the various computers of the Gaussian coefficients, decided me to give equal weight in the combination of the results for the magnetic energy. Thus we have:

Earth's Total Magnetic Energy

1838, ... 0.03635 R^3

1884, ... 0.03532 R^3

Loss in 46 years, ... 0.00103 R^3 or 2.88 per cent, or about $\frac{1}{35}$ part.

This loss is almost entirely in the term representing the portion of the Earth's magnetism to be referred to a homogeneous magnetism, it amounting to 3.15 per cent.

The result is so startling—if it be true, and the loss were to continue at the same rate as during the period 1838–1884, the Earth would lose its entire magnetic energy in about 1,600 years—that extreme caution should be used before coming to a definite conclusion.

Glancing over the results in the last column of Table V, it will be seen that the various values of the magnetic energy for the same epoch and dependent upon practically the same material, differ on the average, about 0.3 per cent, or about $\frac{1}{10}$ of the observed decrease in energy between 1838–1884.

The question as to the effect on the value of the energy due to the completeness or incompleteness of the material employed, is somewhat difficult to determine, as modern constructors of magnetic charts, have not published in detail the material on which the charts are based. Some evidence as to the amount of the effect may be gathered by comparing the 1829 and 1842 values. In both cases the material used extended over a considerable period before and after the epoch selected, in the latter one, however, the material was somewhat more extensive than for the former. Referring the 1829 value to 1842.5, using the annual rate of decrease

$$\frac{.00103}{46} R^3 = 0.0000224\ R^3,$$

Digitized by Google

we obtain for the magnetic energy .03577 R^3, against the mean of the two 1842 results, 0.03648 R^3, hence a difference of 0.00071 R^3 or 1.97 per cent. Whether the difference in the completeness of the material between the 1842 charts, and the 1880 or 1885 charts, is as pronounced as for the comparison just made can not be said off-hand. In certain regions of the Earth, there has been either no gain at all, or very little in the material since the Sabine charts of 1840–1845.

While then the observed decrease in magnetic energy in the interval of 46 years, between 1838 and 1884, is larger than can apparently be ascribed to method of computation of the Gaussian coefficients, or to the character of the material employed, it will be safest, at the present stage, until other related investigations have been completed, to leave open the inquiry whether the Earth's total magnetic energy remains constant, or is suffering an increase or a decrease with the lapse of time.

This investigation, however, most emphatically indicates the great need of a fresh potential computation as dependent upon strictly homogeneous data, distributed fairly uniformly, say between the parallels 60° North and 60° South, the entire data having been obtained within a sufficiently brief interval, to eliminate the effect of secular variation. Thus, in view of the fact, that for very large areas of the globe, as already stated, practically no additional material has been obtained since the epoch for which Sabine drew his magnetic charts of 1840–1845, upon which the results given above for 1840–1845 depend, it may easily happen that the potential expression for 1885 may not represent any very great absolute improvement over that for 1840–1845, no matter how carefully and scientifically the computer may have performed his task. I take this occasion, also, to emphasize the need of complete publication of the original material on which a magnetic chart or a potential computation depends, so that an outsider may obtain some idea as to the amount of reliance to be put upon a chart or upon the results of a potential computation, based thereon.

For the sake of comparison, it may be of interest to give the value of the magnetic energy for the external potential determined by Schmidt and Fritsche. Supposing an internal system, producing equivalent effects on the Earth's surface, to those produced by the external potential, the magnetic energy of this portion would be 0.00000449 R^3, or 0.0125 per cent of the internal portion above given.

Digitized by Google

USES OF THE ENERGY FUNCTION.

Could we assume that the Earth's total magnetic energy remains constant, either in its entirety, or only as far as some of its constituents are concerned, we should have a valuable aid in the energy function for expressing the Gaussian coefficients as functions of the time. In a paper presented to the American Association for the Advancement of Science, in 1894 (See *Proc.* Vol. XLIII, 1894), I showed how past declination and inclination data could be utilized for this purpose. The solution there proposed will be effectively advanced by the use of the energy function. I shall enter into this matter more fully in a paper entitled "On the Time Extension of the Gaussian Analysis."

A few examples will serve to illustrate the practical application of the energy function.

1. *What work is required at Washington to move a unit magnetic pole, repelled by the Earth's field, from a height where the Earth's magnetic force has vanished down to the Earth's surface?*

According to formula three

$$w = d\,W = -\frac{1}{8\pi} V Z\, d\,S \quad .$$

For the case considered, we have, approximately for 1885, in *C. G. S.* units, $V = -0.26\ R$, $Z = 0.57$, $dS =$ element of surface, taken as one square cintemeter. [For many purposes it will be sufficient to take $V/R = -\frac{1}{2} Z$, as will be the case for a homogeneous magnetization.] Taking R in cms. $= 6.37 \times 10^8$,

$$w = \frac{1}{8\pi}[(0.26) \times (0.57) \times 6.37 \times 10^8] = 3.76 \times 10^6 \text{ ergs} = 0.0383$$

kilogrammeters $= 0.277$ foot pounds $= 3\frac{1}{3}$ inch pounds; that is, the work performed would be equal to raising a pound or about a half kilogram, $3\frac{1}{3}$ inches high against the Earth's gravitational force.

For the vicinity of the north magnetic pole, where we may take $Z = 0.61$, $V/R = -0.32$ or about $\frac{1}{2} Z$, $dS = 1$ sq. cm., $w = 4.95 \times 10^6$ ergs $= 0.0504$ kilogrammeters $= 0.365$ foot pounds $= 4.4$ inch pounds. *For points vertically above the magnetic equator*, since here $Z = 0$, $w = 0$. *For the entire Earth*, the mean of the seven values in the last column of Table V gives $W = 0.03576 \times R^6 = 9.243 \times 10^{24}$ ergs $= 9.422 \times 10^{16}$ kgms. $= 68.15 \times 10^{16}$ foot

Digitized by Google

pounds. Per square centimeter of surface we have, $w = 1.812 \times 10^6$ ergs = 0.0185 kgm. = 0.134 foot pounds = 1.6 inch pounds.

By turning back to table V, we find that the average values of the magnetic energy arising from the various constituent portions of the Earth's permanent magnetism are:

	I	II	III	IV	Total
$W/R^3 =$	0.03525	0.000317	0.000153	0.000037	0.03576

Hence W_{II} is about $\frac{1}{100} W_I$, W_{III} is about $\frac{1}{200} W_I$, and W_{IV}, about $\frac{1}{1000} W_I$. The magnetic energy of that portion of the Earth's permanent magnetic field represented by the residual field in No. I of these researches, namely, the terms II, III, and IV, is 0.000507 R^3/0.03525 R^3 or about $\frac{1}{70}$ that arising from the homogenous magnetization taken as the normal field. If simply the homogenous magnetization symmetrical about the Earth's rotation axis be taken as the normal field, then the magnetic energy of the residual portion will be 0.001915 R^3/0.03385 R^3, or $\frac{1}{17.7}$ that of the symmetrical field. This latter ratio is about 100 times that existing between the magnetic energies of the external portion of the diurnal variation field and the external portion of the permanent field.

2. *What is the total work required to remove a gram mass from every point of the Earth's surface to a height where the Earth's gravitational force has vanished?*

If M be the Earth's total mass, r the radius vector to any point in the space outside, then the gravitation potential will be $V = M/r$ and the vertical force, $Z = M/R^2$

$$\text{hence, } dW = \frac{1}{8\pi} VZ\, dS = \frac{1}{8\pi} \frac{M^2}{R^3} dS .$$

Integrating over the entire Earth's surface, in accordance with formula three, we get for the Earth's gravitational energy in the space outside:

$$W = \frac{M^2}{2R} = \frac{(6.14 \times 10^{27})^2}{2 \times 6.37 \times 10^8} = 2.96 \times 10^{46} \text{ ergs} =$$

0.302×10^{39} kgms. = 2.18×10^{39} foot pounds. Per square centimeter, we have, $w = 0.582 \times 10^{28}$ ergs = 0.0593×10^{21} kgms. = 0.429×10^{21} foot pounds. For a square element of surface with sides 0.4 millimeter long, $w = 9.31 \times 10^{24}$ ergs = 9.49×10^{16}

Digitized by Google

kgms. = 68.64 × 10^{16} foot pounds. *Hence the gravitational energy over a square 0.4 mm. of surface is equal to the Earth's total magnetic energy over the entire surface.*

3. An application of the energy function to the *diurnal variation forces* has likewise been made, and it would appear, that if we take into consideration the external portion of the Earth's permanent magnetic field, in addition to the diurnal variation field, we are dealing with a distribution of forces in the upper regions, very similar to that of the permanent field, and that the difference is merely one of degree, and, as to the seat of the forces,—whether internal or external. These calculations will furnish the subject of a separate paper.

LITERATURE.

ADAMS, J. C. AND W. G. Determination of the Gaussian Magnetic Constants. Report Brit. Assoc. Bristol Meeting, 1899.

ADAMS, J. C. The Scientific Papers of John Couch Adams. Vol. II, Cambridge, 1900. [Contains the results of his potential computation for 1840–5 and 1880.]

ERMAN, A., AND PETERSEN, H. Die Grundlagen der Gaussischen Theorie und die Erscheinungen des Erdmagnetismus im Jahre 1829, Berlin, 1874.

FRITSCHE, H. Ueber die Bestimmung der Coefficienten der Gaussischen Allgemeinen Theorie des Erdmagnetismus für das Jahr 1885. St. Petersburg, 1897.

Die Elemente des Erdmagnetismus für die Epochen 1600, 1650, 1700, 1780, 1842 und 1885, und ihre Saecularen Aenderungen. St. Petersburg, 1899.

Die Elemente des Erdmagnetismus und ihre Saecularen Aenderungen während des Zeitraumes 1550 bis 1915. Publication III, St. Petersburg, 1900.

Die tägliche Periode der Erdmagnetischen Elemente, St. Petersburg, 1900.

GAUSS, C. F. Allgemeine Theorie des Erdmagnetismus. "Resultate," 1839, also in Vol. V "Gesammelte Werke." Translated in Taylor's Scientific Memoirs.

ICILIUS, G. v. QUINTUS. Der magnetische Zustand der Erde nach den von der Deutschen Seewarte herausgegebenen magnetischen Karten für 1880.0 Aus d. Arch. d. Deutschen Seew. IV. Jahrg. 1881, Hamburg, 1881.

NEUMAYER, G. Atlas des Erdmagnetismus. Gotha, Justus Perthes, 1891. [Contains the results of the Neumayer-Petersen Computation for 1885.]

SCHMIDT, ADOLF. Mathematische Entwickelungen zur allgemeinen Theorie des Erdmagnetismus aus dem Archiv der Deutschen Seewarte. XII. Jahrg. 1889, Hamburg, 1889.

Mitteilungen über eine neue Berechnung des erdmagnetischen Potentials. Abhandl. der k. bayer. Akad. der Wiss. II. Cl., XIX. Bd., I. Abth., München, 1895.

Der magnetische Zustand der Erde zur Epoche 1885.0, analytisch dargestellt. Aus dem Archiv der Deutschen Seewarte, XXI. Jahrg. 1898, Hamburg, 1898.

SCHUSTER, A. The Diurnal Variation of Terrestrial Magnetism. First paper in Phil. Mag., Apr. 1886; second paper in Phil. Trans. vol. 180 (A), 1889.

The Present Condition of Mathematical Analysis as applied to Terrestrial Magnetism.
Report, Int'l Met'l Congr., Chicago, 1893. Bull. 11 Pt. II, p. 550, U. S. Dep't of Agriculture, Weather Bureau.
[Condition of Analysis of Permanent Field and of Diurnal Variation.]

On some Definite Integrals and a new Method of Reducing a Function of Spherical Co-ordinates to a Series of Spherical Harmonies. Phil. Trans. Roy. Soc. (A), vol 200, 1902.

Digitized by Google

b. THE SEAT OF THE PRINCIPAL CAUSE OF THE SECULAR VARIATION OF THE EARTH'S MAGNETISM.

Innumerable hypotheses have been advanced for the cause of the secular variation, but to my knowledge, the only attempt made to settle the question, which must first be answered, before a successful determination of the cause can be made, as to the *seat* of the cause of the secular variation—whether within the Earth's crust or outside of it,—was my preliminary one, in this Journal, Vol. IV, 1899, pp. 54–58.

I there solved the problem for that portion of the Earth's magnetism, which can be referred to a homogeneous magnetization, with the aid of the following proposition:

"If the observed changes in the compass and the dip needle, can be completely accounted for by hypothetical causes within the Earth's crust, then they can not be produced by causes outside of the crust."

The secular changes in the *compass* needle can equally well be explained by internal or external causes. By taking, however, into account also the secular changes in *dip*, it can be determined whether the principal cause of the secular variation is an internal or an external one.

The general conclusion drawn was, that the seat of the principal cause, was within the Earth's crust.

I shall now reinvestigate this matter, considering this time the changes in the three magnetic elements, declination, dip, and intensity, during the period from 1840–1845 (Sabine's charts), to 1880–1885 (Creak and Neumayer's charts), and use the same analytical method employed by Gauss, in determining whether the Earth's permanent magnetic field arose from an internal or an external system, and later by Schuster, when solving the same question, with respect to the diurnal variation.

The potential due to an internal system of magnetic forces may be expressed as follows:

$$V_i = \frac{R^3}{r^2} \cdot P_1 + \frac{R^4}{r^3} \cdot P_2 + \frac{R^5}{r^4} \cdot P_3 + \ldots, \qquad (1)$$

and the potential due to an external system of magnetic forces:

$$V_e = r \cdot P_1 + \frac{r^2}{R} \cdot P_2 + \frac{r^3}{R^2} \cdot P_3 + \ldots. \qquad (2)$$

Digitized by Google

r, is the radius vector from the center of the Earth to the point considered; R, the Earth's mean radius, and P_1, P_2, P_3, etc., surface spherical harmonics.

On the surface of the Earth, $r = R$, we have

$$V_i = V_e, \quad X_i = X_e \text{ and } Y_i = Y_e \quad , \tag{3}$$

$$Z_i = -2P_1 - 3P_2 - 4P_3 - \ldots \quad , \tag{4}$$

$$Z_e = +P_1 + 2P_2 + 3P_3 + \ldots \quad . \tag{5}$$

Hence, with the aid of the vertical force, it can be ascertained whether the system producing a given magnetic distribution, is an internal or an external one, or both. For a system of coefficients which will satisfy the X and Y values on the Earth's surface, can not fulfill at the same time, both conditions expressed by the Z_i and Z_e equations. *If the Z_i condition is fulfilled, then the system is an internal one, and if, on the other hand, the Z_e condition is satisfied, then the system is an external one, at least as far as the principal effects are concerned.* Again, by the degree of divergence in the fulfillment of either condition, it can be determined as to how much of the observed effects are to be ascribed to a system external to the principal one.

This is the method used by Gauss and Schuster, when solving their respective problems, as already stated.

Precisely similar equations, to the above hold for any magnetic variation possessing a potential. Let dV, dX, dY, and dZ, represent, respectively, the average annual change in V, X, Y, and Z, during the interval 1840–1845 to 1880–1885, *i. e.*, during a period about forty-two years. Furthermore, X_1, Y_1, Z_1, and X_2, Y_2, Z_2, shall represent, respectively, the mean magnetic components along a complete parallel of latitude, for the early and the later epoch.

$$\Delta X = X_1 - X_2 \quad , \Delta Y = Y_1 - Y_2 \quad , \Delta Z = Z_1 - Z_2$$

$$dX = \tfrac{1}{32}\,\Delta X \quad , dY = \tfrac{1}{32}\,\Delta Y \quad , dZ = \tfrac{1}{32}\,\Delta Z \; .$$

We have to terms of the fourth order:

$$X = -g_{10}\sin u - 2\,g_{20}\sin u\cos u - 3\,g_{30}(\cos^2 u - \tfrac{1}{5})\sin u - 4\,g_{40}(\cos^2 u - \tfrac{3}{7})\sin u\cos u \quad , \tag{6}$$

$$Y = 0 \quad , \tag{7}$$

$$Z_i = -2\,g_{10}\cos u - 3\,g_{20}(\cos^2 u - \tfrac{1}{3}) - 4\,g_{30}(\cos^2 u - \tfrac{3}{5})\cos u - 5\,g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad , \tag{8}$$

$$Z_e = +g_{10}\cos u + 2\,g_{20}(\cos^2 u - \tfrac{1}{3}) + 3\,g_{30}(\cos^2 u - \tfrac{3}{5})\cos u + 4\,g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad . \tag{9}$$

Digitized by Google

These equations being linear in the coefficients g, precisely similar equations pertain to the differentials; we have simply to substitute dX for X, dg for g, etc.

If, as is usually done in the initial steps of a potential computation, the X, Y, Z, components for points along the same parallel of latitude, are expressed in the form of a series:

$$X = m_0 + m_1 \cos \lambda + M_1 \sin \lambda + m_2 \cos {}_2\lambda + M_2 \sin {}_2\lambda + \ldots \quad (10)$$

$$Y = l_0 + l_1 \cos \lambda + L_1 \sin \lambda + l_2 \cos {}_2\lambda + L_2 \sin {}_2\lambda + \ldots \quad (11)$$

$$Z = k_0 + k_1 \cos \lambda + K_1 \sin \lambda + k_2 \cos {}_2\lambda + K_2 \sin {}_2\lambda + \ldots \quad (12)$$

then will $X = m_0$, $Y = l_0$ and $Z = k_0$. (13)

$$\Delta X = \Delta m_0 \text{ , } \Delta Y = \Delta l_0 \text{ and } \Delta Z = \Delta k_0 \quad . \quad (14)$$

The values of m_0, l_0, k_0, have been determined by Adams and Fritsche, from the magnetic elements on Sabine's charts for 1840–1845, by Adams for 1880, from Creak's chart of 1880, and by Fritsche, Neumayer and Schmidt, from Neumayer's chart for 1885. As Fritsche's values for 1842 are dependent upon scalings for points 30° apart in longitude, and his later values for 1885 for points 15° apart in longitude, whereas Adams' values for both epochs depend upon scalings 10° apart, I have confined myself for the m_0 values entirely to the latter's values, as representing fuller and more homogeneous data.

Theoretically, according to the above formulæ, $Y = l_0 = 0$. As a matter of fact, however, l_0 is not quite equal to zero,[1] thus indicating the possible existence of effects arising from a system not possessing a potential, *e. g.*, electric currents passing vertically through the Earth's crust, either from within or without, or from both sources. However, the departures from zero are of such an amount, that for the present investigation, we can leave them out of consideration. We can thus confine ourselves entirely to determining Δg_{10}, Δg_{20}, Δg_{30}, Δg_{40}, from the $\Delta X = \Delta k_0$ values. If the values thus found, satisfy the ΔZ_i equation, then it has been proven that the seat of the principal source of the secular variation is within the Earth, and if, on the other hand, the ΔZ_e condition is better fulfilled, then the seat is outside of the Earth.

If Δk_0 and $\Delta k_0'$, represent the average ΔX values on two parallels, u and $180-u$ (*i. e.*, on two parallels equi-distant from the equator), we have the conditional equations:

[1] *T. M.* Vol. II, p. 17.

Digitized by Google

$$\tfrac{1}{2}(\Delta k_0 + \Delta k'_0) = -\Delta g_{10} \sin u - 3\,\Delta g_{30}(\cos^2 u - \tfrac{1}{5}) \sin u \quad , \quad (15)$$

$$\tfrac{1}{2}(\Delta k_0 - \Delta k'_0) = -2\,\Delta g_{20} \sin u \cos u - 4\,\Delta g_{40}(\cos^2 u - \tfrac{3}{7}) \sin u \cos u \quad , \quad (16)$$

for each pair of parallels employed, viz: 60° N. and S., 50° N. and S., 40° N. and S., 30° N. and S., 20 N. and S., and 10° N. and S., the equator not being used, so as to preserve the uniformity of the system of equations.

	½ ($k_0 + k'_0$) Brit. Units.		½ ($k_0 + k'_0$) C. G. S. Units.		½ ($\Delta k_0 + \Delta k'_0$) C. G. S. Units.		½ ($\Delta k_0 - \Delta k'_0$) C. G. S. Units.	
Parallels	1842.5	1880	1842.5	1880	Observ'd	Comp'd	Observed	Comp'd
60 N. and S.	3.1453	3.0990	0.1450	0.1429	+ 0.0021	+ 0.0039	— 0.0020	— 0.0012
50 " " "	4.1814	4.0501	0.1928	0.1867	+ 61	+ 48	— 42	— 46
40 " " "	5.1196	4.9913	0.2361	0.2301	+ 60	+ 55	— 78	— 81
30 " " "	5.9998	5.8674	0.2766	0.2705	+ 61	+ 60	— 96	— 101
20 " " "	6.7362	6.6060	0.3106	0.3046	+ 60	+ 63	— 82	— 92
10 " " "	7.2384	7.1009	0.3337	0.3274	+ 63	+ 64	— 70	— 55

The values ½ ($k_0 + k'$) and ½ ($k_0 - k'$), as used in above table, have been taken from Vol. II, pp. 520–523, of "The Scientific Papers of John Couch Adams;" they are given there in British units, and have been converted by me into C. G. S. units. Columns 6 and 8, give the quantities used in the determination of the values Δg by least squares. The first number in column 6, for instance, represents the average secular change in the X component along the parallels 60° N. and S., for the entire interval 1842.5 to 1880, the plus sign signifying that X, on the average, decreased during that period. To obtain the average annual change, dX, the numbers would have to be divided by the elapsed interval of 37.5 years.

The resulting values of Δg, expressed in C. G. S. units, are: $\Delta g_{10} = -0.00685$, $\Delta g_{20} = +0.00795$, $\Delta g_{30} = -0.00047$, and $\Delta g_{40} = -0.01025$. Hence the annual increments from division by 37.5: $dg_{10} = -0.000183$, $dg_{20} = +0.000212$, $dg_{30} = -0.000013$, $dg_{40} = -0.000273$.

How closely the computed Δg's[1] will reproduce the observed values, can be seen from columns 7 and 9.

[1] We have a check upon our values from Adams' own computations. He computed the g's for both epochs, once from the X and Y components alone, and next from the Z components, and thus got two sets of values for each epoch (see p. 607 of volume above cited); his values are slightly different from mine as he included terms to the 6th order. Converting into C. G. S. units we obtain from his X, Y, figures: $\Delta g_{10} = -0.0066$, $\Delta g_{20} = +0.0077$, $\Delta g_{30} = -.0006$, $\Delta g_{40} = -0.0094$, $\Delta g_{50} = +0.0033$, and $\Delta g_{60} = +0.0042$.

Digitized by Google

If now the principal cause of the secular variation is an internal one, then the above Δg values must satisfy this condition:

$$\Delta Z_i = -2\,\Delta g_{10}\cos u - 3\,\Delta g_{20}(\cos^2 u - \tfrac{1}{3}) - 4\Delta g_{30}(\cos^2 u - \tfrac{3}{5})\cos u - 5\Delta g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad . \qquad (17)$$

If, on the other hand, the principal cause is an external one, then the other condition must be fulfilled:

$$\Delta Z_e = +\Delta g_{10}\cos u + 2\,\Delta g_{20}(\cos^2 u - \tfrac{1}{3}) + 3\,\Delta g_{30}(\cos^2 u - \tfrac{3}{5})\cos u + 4\,\Delta g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad . \qquad (18)$$

The figures in the following table show the result of the test of both hypotheses; the value of each term in each expression is given, so as to show its effect and magnitude. It is most instructive to exhibit the law of variation in ΔZ from parallel to parallel, instead of a pair of equi-distant parallels, and as Adams only gives the Z^m (or m_o) values for pairs of parallels, I have made use of de Tillo's tabulations of Z, for points 10° apart in longitude. All the quantities in the table are in terms of the fourth decimal, C. G. S., units, hence, in terms of 10γ.

	Observation.			I. Computation: cause internal						II. Computation: cause external					
Lat.	$Z^m = m_o$		ΔZ_o^m	Term				I ΔZ_c^m	Obs'd-Co'pd	Term				E ΔZ_c^m	Obs'd-Co'pd
	1842.5	1885	'42–'85	1	2	3	4			1	2	3	4		
N60°	−5488	−5430	+58	−119	−99	+2	+0	+22	+36	−59	+66	−2	−0	+5	+53
50°	−5032	−5000	+32	−105	−60	0	−4	+41	−9	−52	+40	0	+3	−9	+41
40°	−4420	−4303	+117	−88	−19	−2	−5	+62	+55	−44	+13	+2	+4	−25	+142
30°	−3449	−3464	−15	−68	+20	−3	−3	+82	−97	−34	−13	+2	+3	−42	+27
20°	−2340	−2295	+55	+47	+51	−3	0	+95	−40	−23	−34	+2	0	−55	+110
10°	−1124	−1022	+102	−24	+72	−2	+3	+91	−11	−12	−48	+2	−3	−61	+163
Equ'r	−96	−221	+125	0	+79	0	+4	+83	+42	0	−53	0	−4	−57	+182
10°	−1262	−1359	+97	−24	+72	+2	+3	+53	+44	+12	−48	−2	−3	−41	+138
20°	−2286	−2398	+112	−47	+51	+3	0	+7	+105	+23	−34	−2	−0	−13	+125
30°	−3200	−3226	+26	−68	+20	+3	−3	−48	+74	+34	−13	−2	+3	+22	+4
40°	−4087	−3927	+160	−88	−19	+2	−5	−110	−50	+44	+13	−2	+4	+59	+219
50°	−4823	−4600	+223	−105	−60	0	−4	−169	−54	+52	+40	0	+3	+95	+318
S60°	−5437	−5209	+228	−119	−99	−2	0	−220	−8	+59	+66	−2	0	+127	+355

The fourth column contains the secular change in the vertical component during the interval 1842.5 to 1885, on the average, for the respective parallel opposite to which it stands, a plus sign signifying that the vertical force has decreased during the said period. The columns marked I and E, respectively, give the computed secular changes for the two hypotheses: internal and external; the residuals contained in the columns adjacent (on the right) to I and E,

Digitized by Google

enable one to judge as to which of the two hypotheses appears the more probable one. It is readily seen that the hypothesis of an internal cause gives the smaller residuals. The diagram (Fig. 1) tells the story best.

The curves shown, express the law of variation in the average secular change of the vertical component, from parallel to parallel, the full curve as dependent on observations between 1842 and 1885, the broken curve being the computed variation upon the hypothesis of an internal cause, whereas the dotted curve being the computed variation as on the hypothesis of an external one. It will be noticed, that while the observed curve is irregular, it agrees in general well with the internal-cause curve, and disagrees markedly from the external-cause curve.

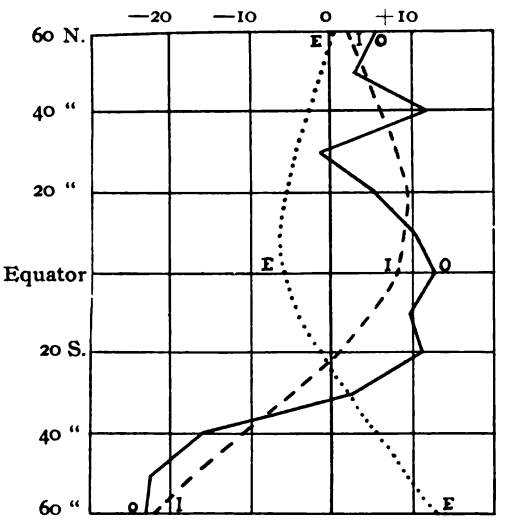


FIG. 1. Comparison of observed (full curve) with computed secular variation (broken curve supposing cause internal, and dotted curve supposing cause external.)

In order to find out whether the irregularities in the observed curve are due to errors in de Tillo's tabulated quantities, I have also plotted the curve as dependent on Fritsche's m_0 values for 1842.5 and 1885; his first values, as already stated, depend upon 30° scalings, and the latter upon scalings made 15° apart in longitude. The curve thus obtained, agreed so well with the one already given, that, to avoid confusion, it was omitted in the reproduction. The irregularities are, therefore, inherent in the primary quantities, and

Digitized by Google

from other investigations, I am conducting, I am inclined to think that they are, to a large extent, facts of nature. These irregularities are most pronounced near parallels 20–30, N. and S.—parallels of such interest to the meterologist.

It is quite possible, of course—in fact probable—that in addition to the main internal cause of the secular variation, there is, in addition, a subordinate, external cause. The investigation of this is reserved for a future paper.

The conclusion drawn from this paper, is that:

The main cause of the secular variation of the Earth's magnetism is due to a system of forces imbedded in the Earth, and not to an external system. This does not exclude there being, in addition, an external system producing minor effects. The main cause is due, furthermore, to a system of forces possessing a potential.

c. ON THE IMPROVEMENT OF THE GAUSSIAN THEORY OF THE EARTH'S MAGNETISM.

As it is my intention to make some time a new mathematical analysis of the Earth's magnetic field, on somewhat different principles than hitherto employed, I am making a critical examination and comparison of the results obtained thus far by the various analysts, with the view of ascertaining precisely wherein improvement is required. The conclusions reached, thus far, follow from the tables herein presented.

Table *A*, gives the residuals obtained by subtracting the computed X components from the so-called observed values or values based upon the magnetic charts used in the potential computation. Thus, beginning with the second column, marked F, we have the residuals for every 30° in longitude along the parallel 60° N, the computed quantities, X_c, resulting from Fritsche's analysis for 1840–1845, as dependent upon the Sabine's charts for that period. Fritsche scaled from these maps, the declination, inclination, and horizontal intensity for every 10th degree parallel, 80 N. to 80 S., and for every 30th degree meridian, and from these scaled quantities, computed the X_o, Y_o, Z_o's. Having deduced the Gaussian coefficients to terms of the sixth order, as given in the table in section *a* of this paper, he next computed the X_c, Y_c, Z_c's, and formed the residuals, which are here reproduced with the signs changed to conform with the notation adopted in this paper. [X + north, Y or D, + east, Z or I, + down, $\Delta X = X_o - X_c$ etc.]

Digitized by Google

TABLE A. Residuals of X components for 1842.5 and 1885, according to Fritsche and Schmidt. ($X_o - X_c$).

[Expressed in units of fourth decimal, *C. G. S.*]

	1842	60° N. 1885			1842	40° N. 1885			1842	20° N. 1885			1842	Equator. 1885			1842	20 S. 1885			1842	40 S 1885			1842	60 S. 1885			
λ E of Gr	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	λ E of Gr
°																													°
0	+ 13	+ 71	— 5	+ 76	— 61	— 3	+45	— 48	+ 10	60	—35	— 25	+ 92	+ 29	+14	+ 15	— 98	—90	—49	—41	—70	—17	+21	— 38	— 61	—121	—43	— 78	0
15		+ 99	— 6	+105		— 31	+ 5	— 36		— 65	—24	— 41		+ 31	+11	+ 20		—40	—20	— 20		+10	+39	— 29		—122	—40	— 82	15
30	+ 7	+131	+ 12	+119	— 78	— 16	—16	0	+232	— 50	—16	— 34	—144	— 9	+13	— 22	— 99	— 6	+10	—16	—35	+48	+29	+ 19	— 78	— 81	—16	— 65	30
45		+141	+ 35	+106		+ 14	—26	+ 40		— 11	— 3	— 8		— 46	+23	— 69		0	+17	— 17		+77	— 1	+ 78		— 65	—21	— 44	45
60	+ 70	+138	+ 51	+ 87	+ 38	+ 25	—40	+ 65	— 30	+ 35	+13	+ 22	+ 81	— 70	+ 8	— 78	+ 51	+11	+19	— 8	+52	+91	—14	+105	— 31	— 70	—35	— 35	60
75		+120	+ 41	+ 79		+ 37	—38	+ 75		+ 95	+50	+ 45		— 73	—26	— 47		+ 1	— 9	+10		+73	—10	+ 83		—104	—61	— 43	75
90	+ 24	+135	+ 52	+ 83	+ 81	+ 45	—39	+ 84	+122	+ 69	+16	+ 53	+194	— 13	— 4	— 9	+ 65	— 9	—23	+14	+11	+55	+16	+ 39	— 38	— 93	—48	— 45	90
105		+156	+ 70	+ 86		+ 71	— 8	+ 79		+ 17	—32	+ 49		+ 11	+11	0		—11	—12	+ 1		+64	+ 43	+ 21		+ 3	+18	— 15	105
120	+ 52	+134	+ 54	+ 80	+ 11	+ 58	+ 7	+ 51	+ 85	+ 10	—22	+ 41	+118	+ 30	+31	— 1	+ 33	+ 8	+11	— 3	—37	+82	+35	+ 47	— 24	+ 21	—26	+ 47	120
135		+ 76	+ 6	+ 70		+ 44	+31	+ 13		+ 35	—12	+ 47		+ 98	+70	+ 28		+50	+35	+15		+95	+10	+ 85		+ 31	—72	+103	135
150	+ 27	+ 32	— 49	+ 81	— 81	+ 59	+52	+ 7	+ 73	+ 66	— 6	+ 72	+ 93	+ 58	—20	+ 78	+ 8	+81	+36	+45	—78	+46	—45	+ 91	+ 43	+ 32	—89	+121	150
165		+ 32	— 81	+113		+ 60	+ 9	+ 51		+105	+ 4	+101		— 50	—61	+111		+94	+31	+63		+19	—35	+ 54		+ 12	—74	+ 86	165
180	+ 5	+ 43	—107	+150	+ 40	+ 34	—71	+105	— 4	+113	+12	+101	+ 80	+112	+11	+101	+210	+96	+33	+63	—32	+12	+11	+ 1	+ 8	+ 13	—18	+ 31	180
195		+ 61	— 99	+160		+ 55	—54	+109		+ 94	+26	+ 68		+ 87	+15	+ 72		+83	+28	+55		+12	+ 45	— 33		+ 30	+40	— 10	195
210	— 66	+ 87	— 48	+135	+ 19	+ 84	+28	+ 56	— 40	+ 28	+ 7	+ 21	+143	+ 35	—20	+ 55	+ 63	+56	+11	+45	+ 5	—27	+12	— 39	+ 39	+ 51	+62	— 11	210
225		+ 88	— 14	+102		+ 68	+64	+ 4		— 6	—10	+ 4		— 11	—64	+ 53		+19	— 3	+22		—60	—31	— 29		+ 70	+63	+ 7	225
240	— 1	+ 88	— 1	+ 89	— 24	+ 40	+30	+ 10	— 14	— 11	—28	+ 17	+147	+ 52	+ 7	+ 45	+ 92	+22	+26	— 4	— 2	—57	—44	— 13	+111	+ 87	+66	+ 21	240
255		+ 82	— 15	+ 97		+ 78	+17	+ 61		— 11	—53	+ 42		+ 45	+13	+ 32		+45	+56	—11		—26	—18	— 8		+ 75	+68	+ 7	255
270	+ 6	+ 7	— 97	+104	— 38	+ 83	—18	+101	+ 69	+ 18	—32	+ 50	+ 17	+ 23	— 7	+ 30	— 60	+32	+17	—15	+65	+ 5	+ 7	— 2	+ 34	+ 5	+32	— 27	270
285		+ 33	— 54	+ 87		+105	+16	+ 89		+ 57	+17	+ 40		— 2	—42	+ 40		+ 5	—41	+46		+31	+29	+ 2		+ 3	+64	— 61	285
300	— 22	+ 43	— 8	+ 51	—112	+ 28	—17	+ 45	+ 40	+ 68	+34	+ 34	+ 67	— 37	—77	+ 40	— 57	+22	—20	+42	+42	0	— 9	+ 9	— 11	— 9	+66	— 75	300
315		+ 11	— 8	+ 19		— 41	—43	+ 2		+ 37	+ 3	+ 34		+ 61	+46	+ 15		+23	+27	— 4		—17	—26	+ 9		— 60	+10	— 70	315
330	+ 32	+ 3	— 9	+ 12	+ 52	— 48	—27	— 21	— 60	— 26	—53	+ 27	+ 97	+ 30	+43	— 13	+ 41	—24	+28	—52	— 4	—33	—36	+ 3	+ 47	— 89	—28	— 61	330
345		+ 38	+ 2	+ 36		— 5	+34	— 39		— 36	—40	+ 4		— 7	+ 1	— 8		—75	—10	—65		—32	12	— 20		—114	—48	— 66	345
Mean	27.1	77.1	38.5	88.6	52.9	47.2	30.6	49.6	64.9	47.2	22.8	40.8	10.6	42.5	26.6	40.9	73.1	38.0	23.8	29.5	36.1	41.2	24.1	35.7	43.8	57.1	46.2	50.5	Mean

Digitized by Google

TABLE B. Residuals of Y components for 1842.5 and 1885, according to Fritsche and Schmidt. $(Y_o - Y_c)$.

[Expressed in units of fourth decimal, *C. G. S.*]

	1842	60° N. 1885			1842	40° N. 1885			1842	20° N. 1885			1842	Equator. 1885			1842	20° S 1885			1842	40° S. 1885			1842	60° S. 1885			
λ *E* of Gr	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	λ *E* of Gr
0	− 40	−22	+44	−66	+22	+47	+ 34	+13	− 23	+111	+23	+ 88	−41	+ 44	− 20	+ 64	−12	−18	− 5	−13	+ 33	+ 27	+ 56	− 29	+ 14	+ 29	+ 49	− 20	0
15		−29	− 6	−23		−18	− 25	+ 7		+ 25	+25	0		+ 28	+ 40	− 12		+11	+24	−13		− 26	− 18	− 8		+ 24	+ 37	− 13	15
30	− 15	−16	−44	+28	−54	−44	− 53	+ 9	−106	− 58	+18	− 76	+12	− 22	+ 54	− 76	+ 7	− 5	− 6	+ 1	− 15	− 69	− 85	+ 16	− 21	+ 28	+ 33	− 5	30
45		+ 25	−34	+ 59		−13	− 42	+29		− 58	+ 7	− 65		− 33	+ 20	− 53		−14	−17	+ 3		− 91	− 79	− 12		+ 37	+ 42	− 5	45
60	+ 54	+ 62	+ 2	+ 60	− 3	+37	+ 5	+32	− 56	− 49	−43	− 6	−52	− 18	− 29	+ 11	+29	+17	+38	−21	+ 57	− 69	+ 10	− 79	+ 53	+ 33	+ 43	− 10	60
75		+ 69	+33	+36		+ 60	+ 53	+ 7		− 29	−48	+ 19		− 23	− 66	+ 43		−14	+27	-41		− 59	+ 54	−113		+ 15	+ 6	+ 9	75
90	+ 40	+36	+19	+17	−83	+87	+106	−19	− 35	+ 19	+21	− 2	−21	+ 10	− 24	+ 34	−14	+ 1	+21	−20	− 71	− 36	+ 23	− 59	+ 28	+ 16	− 47	+ 63	90
105		+ 2	−15	+17		+29	+ 27	+ 2		+ 69	+72	− 3		+ 67	+ 42	+ 25		+39	+ 4	+35		+ 9	− 30	+ 39		+116	− 6	+122	105
120	− 50	+ 7	−23	+30	−77	−12	− 67	+55	+ 5	+ 36	− 5	+ 41	+24	+ 58	+ 20	+ 38	−35	+62	− 5	+67	+ 23	+ 63	− 26	+ 89	+156	+147	+ 9	+138	120
135		−20	−48	+28		−52	−123	+71		+ 13	−54	+ 67		+ 11	− 34	+ 45		+27	−15	+42		+ 24	− 19	+ 43		+ 72	− 18	+ 90	135
150	+ 30	−12	−22	+10	−51	+ 8	− 8	+16	− 2	+ 18	− 8	+ 26	− 6	+ 31	+ 2	+ 29	+43	+14	+21	− 7	+ 2	− 36	+ 19	− 55	+ 8	+ 9	+ 3	+ 6	150
165		+30	+33	− 3		+43	+ 90	−47		+ 24	+54	− 30		+ 39	+ 21	+ 18		−11	+15	−26		− 76	+ 39	−115		− 2	+ 60	− 62	165
180	+109	+41	+26	+15	0	+46	+ 87	−41	− 16	+ 3	+30	− 27	−44	+ 30	+ 5	+ 25	− 8	−40	−29	−11	− 23	− 73	+ 26	− 99	− 52	− 29	+ 52	− 81	180
195		+31	−25	+56		− 9	− 40	+31		− 31	−54	+ 23		− 4	− 20	+ 16		−30	−25	− 5		− 58	− 20	− 38		− 65	− 6	− 59	195
210	− 10	− 6	−86	+80	+41	− 9	− 85	+76	+ 25	− 14	−42	+ 28	+99	− 66	− 26	− 40	−11	−12	+ 22	−34	− 22	− 24	− 34	+ 10	− 76	− 77	− 45	− 32	210
225		−11	−79	+68		− 3	− 31	+28		− 16	+26	− 42		−100	+ 11	−111		−11	+60	−71		− 22	− 37	+ 15		− 93	− 60	− 33	225
240	− 17	+ 5	−24	+29	− 9	− 8	+ 51	−59	− 53	− 47	+59	−106	−45	−125	− 11	−114	+39	−20	+48	−68	− 18	− 63	− 47	− 16	− 63	− 87	− 22	− 65	240
255		+ 1	− 3	+ 4		+17	+103	−86		− 62	+17	− 79		− 74	− 39	− 35		−22	+12	−34		− 81	− 26	− 55		− 46	+ 62	−108	255
270	− 26	−30	−36	+ 6	+13	− 1	+ 28	−29	+ 16	− 43	−53	+ 10	−14	+ 11	− 23	+ 34	+38	− 4	+ 6	−10	+ 81	− 26	+ 39	− 65	+ 37	+ 49	+173	−124	270
285		+23	0	+23		+ 8	− 36	+44		− 8	−59	+ 51		− 43	− 50	+ 7		−55	−32	−23		− 25	+ 8	− 33		+ 77	+177	−100	285
300	− 3	−17	−33	+16	−14	+ 5	− 57	+62	− 20	+ 45	+35	+ 10	−38	− 12	+ 70	− 82	−54	−68	−19	−49	+ 20	− 40	− 67	+ 27	+ 60	+ 29	+ 77	− 48	300
315		−12	+ 7	−19		+36	+ 5	+31		+ 32	+60	− 28		+ 8	+124	−116		−32	+15	−47		− 6	− 69	+ 63		+ 14	+ 23	− 9	315
330	− 19	−18	+44	−62	+54	+40	+ 33	+ 7	+ 38	− 52	−66	+ 14	+29	− 98	− 58	− 40	+36	−14	+13	27	+ 14	+ 42	− 5	+ 47	+ 16	+ 9	+ 8	+ 1	330
345		−26	+56	−82		+56	+ 51	+ 5		+ 71	−16	+ 87		− 65	−121	+ 56		− 1	+11	−12		+ 60	+ 62	− 2		+ 25	+ 36	− 11	345
Mean	34.4	23.0	30.9	34.9	35.1	28.7	51.7	33.5	32.9	38.9	37.3	38.7	35.4	42.5	38.7	46.8	27.1	22.6	20.4	28.3	31.6	46.1	37.4	46.9	48.7	47.0	45.6	50.6	Mean

Digitized by Google

TABLE C. *Residuals of Z Components for 1842.5 and 1885, according to Fritsche and Schmidt.* ($Z_o - Z_c$).

[Expressed in units of fourth decimal, *C. G. S.*]

	1842	60° N. 1885			1842	40° N. 1885			1842	20° N. 1885			1842	Equator. 1885			1842	20 S. 1885			1842	40° S. 1885			1842	60° S. 1885			
λ *E* of *Gr*	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	λ *E* of *Gr*
°																													°
0	+ 8	+ 32	− 61	+ 93	− 38	+ 35	+ 38	− 3	+151	− 89	− 26	− 63	− 13	− 68	− 67	− 1	+ 73	+117	− 4	+121	+150	+ 70	− 39	+109	+133	+ 78	+ 22	+ 56	0
15		+ 2	− 79	+ 81		− 33	− 38	+ 5		−134	− 80	− 54		−131	− 89	− 42		+121	+83	+ 38		+107	+ 48	+ 59		+ 38	− 8	+ 46	15
30	− 74	+ 52	+ 21	+ 31	+ 60	−104	− 60	− 44	− 15	− 58	+ 22	− 80	+ 3	− 83	+ 7	− 90	+ 3	+ 9	+54	− 45	+ 18	+ 90	+ 89	+ 1	+ 19	+ 20	− 12	+ 32	30
45		+117	+151	− 34		− 97	+ 8	−105		− 38	+ 51	− 89		0	+ 79	− 79		−111	−54	− 57		+ 2	+ 20	− 18		+ 4	− 16	+ 20	45
60	− 10	+117	+202	− 85	+127	−102	+ 13	−115	+ 4	− 53	− 19	− 34	+ 34	+ 48	+ 65	− 17	+137	− 74	−67	− 7	+ 14	− 39	− 43	+ 4	+ 74	+ 29	+ 14	+ 15	60
75		+ 9	+113	−104		− 94	− 24	− 70		− 34	− 69	+ 35		+ 35	+ 19	+ 16		− 37	−64	+ 27		− 8	− 39	+ 31		+ 83	+ 74	+ 9	75
90	+ 77	− 91	+ 7	− 98	+ 46	−128	−103	− 25	+ 16	− 49	− 86	+ 37	− 8	− 57	− 28	− 29	+ 71	− 33	−56	+ 23	− 36	+107	+ 73	+ 34	+130	− 24	− 19	− 5	90
105		− 99	− 20	− 79		− 81	− 74	− 7		− 19	− 5	− 14		− 69	+ 18	− 87		− 45	−50	+ 5		+109	+161	+ 8		− 26	0	− 26	105
120	+135	− 91	− 31	− 60	+ 20	+ 10	+ 18	− 8	+ 33	+ 41	+ 61	− 20	+ 26	+ 6	+ 67	− 61	+161	− 40	−52	+ 12	− 13	+151	+182	− 31	+ 14	− 38	+ 6	− 44	120
135		− 72	− 22	− 50		+ 14	+ 26	− 12		+ 81	+ 48	+ 33		+ 21	− 16	+ 37		− 52	−80	+ 28		+ 38	+105	− 67		+126	+165	− 39	135
150	+ 31	−204	−162	− 42	+ 74	− 37	+ 4	− 41	+ 55	+ 19	− 36	+ 55	− 20	− 14	−101	+ 87	+ 26	− 11	−34	+ 23	+ 82	+ 96	+163	− 67	− 6	+362	+365	− 3	150
165		−216	−185	− 31		− 90	+ 16	−106		−114	− 74	− 40		− 14	− 32	+ 18		+ 30	+38	− 2		+ 23	+ 45	− 22		+133	+ 77	+ 56	165
180	+ 40	−140	−134	− 6	− 7	−133	+ 30	−163	−116	−172	+ 1	−173	+197	− 21	+ 72	− 93	+175	+ 0	+15	− 15	+ 85	− 32	− 69	+ 37	+102	+ 33	− 75	+108	180
195		+ 23	− 16	+ 39		−154	− 11	−143		−140	+ 54	−194		− 42	+ 72	−114		− 10	+ 0	− 10		− 78	−136	+ 58		− 58	−184	+126	195
210	− 75	+133	+ 43	+ 90	− 86	−142	− 91	− 51	− 48	− 35	+ 43	− 78	−109	− 51	− 24	− 27	− 22	− 27	−26	− 1	+ 14	− 5	− 22	+ 17	+ 34	−105	−210	+105	210
225		+153	+ 37	+116		−108	−134	+ 26		+ 59	+ 24	+ 35		− 16	− 78	− 62		− 34	−35	+ 1		+ 61	+108	− 47		−131	−191	+ 60	225
240	+ 84	+254	+145	+109	− 45	− 98	−110	+ 12	− 10	+ 57	+ 39	+ 18	− 2	+ 7	− 56	+ 63	− 15	+ 10	− 5	+ 15	− 16	+ 36	+101	− 65	− 38	−181	−203	+ 22	240
255		+118	+ 47	+ 71		− 35	+ 24	− 59		+ 25	+101	− 76		+ 7	+ 1	+ 6		+ 85	+38	+ 47		− 11	+ 19	− 30		−220	−223	+ 3	255
270	− 27	−533	−563	+ 30	+ 20	− 77	+ 22	− 99	+ 14	− 71	+ 21	− 92	+ 40	+ 1	+ 20	− 19	0	+102	+44	+ 58	− 55	− 55	− 61	+ 6	−107	−153	−154	+ 1	270
285		+187	+184	+ 3		+ 20	+ 91	− 71		− 71	− 77	+ 6		− 17	− 30	+ 13		+ 21	+ 3	+ 18		− 78	− 77	− 1		+ 13	+ 10	+ 3	285
300	− 41	+116	+119	− 3	+ 17	−102	− 71	− 31	+ 27	+ 9	− 94	+103	+ 59	− 33	− 73	+ 40	+157	− 58	−16	− 42	− 78	− 7	+ 28	− 35	+ 22	+231	+224	+ 7	300
315		+ 63	+ 53	+ 10		−187	−160	− 27		+ 99	+ 15	+ 84		+ 57	+ 30	+ 27		− 50	0	− 50		− 14	+ 18	− 32		+261	+242	+ 19	315
330	− 8	+ 90	+ 54	+ 36	+ 24	−154	−107	− 47	− 36	+ 83	+ 94	− 11	+ 38	+ 54	+ 50	+ 4	− 4	+ 69	+43	+ 26	− 1	− 24	− 53	+ 29	+ 65	+130	+ 93	+ 37	330
345		+134	+ 63	+ 71		− 31	+ 7	− 38		+ 12	+ 82	− 70		− 38	− 41	+ 3		+157	+43	+114		+ 7	− 87	+ 34		+ 61	+ 9	+ 52	345
Mean	50.8	127	105	57.2	47.0	86.1	53.3	54.5	43.8	65.1	50.9	62.2	45.8	37.1	47.3	43.1	70.3	54.5	35.2	32.7	46.8	54.5	82.7	37.6	62.0	106	108	37.2	Mean

Digitized by Google

The third column, marked NF, gives the residuals for 1885, resulting from Fritsche's analysis for that date; the residuals are given this time for every 15° in longitude, since in this instance, Fritsche based his computation on quantities scaled from Neumayer's charts for every 15th degree meridian.

The fourth column, marked NS, gives the residuals resulting from Schmidt's analysis for 1885, and the fifth column, marked SF, the residuals between Schmidt's X_c values and Fritsche's (S–F).

At the bottom of the columns we have the mean residuals, supposing all residuals to have the same sign.

Tables B and C, give similarly, the Y and Z residuals.

All of the 1885 residuals in the three tables have been formed by myself, starting with the "observed" components given in Schmidt's publications, and have been checked with the aid of such tables as have been published. Various typographical errors appear to have crept into Schmidt's own tables of residuals, as given in his publications II and III. Fritsche appears to have published the residuals ΔX, ΔY, ΔZ, only for 1842.

I present the residuals simply for parallels 20° apart, from 60 N. to 60 S., as sufficient for the present purpose.

Table D gives the probable errors, r, for each parallel, as based upon the residuals in the foregoing tables, supposing the chart values to be standard ones. If η is the mean residual (regardless of sign), as given at the bottom of the foregoing tables, then, with sufficient approximation for our immediate object, $r = \pm 0.845\ \eta$. At the bottom of this table, the probable errors are given for a mean parallel.

Table E gives the probable errors for the Gaussian analysis (1830), and the Erman-Petersen analysis for 1829; this table is taken directly from the latter's publication (p. 24), the quantities having been converted, however, from conventional Gaussian units into C. G. S., units (1 $C.\ G.\ U = 0.0003494$ C. G. S.). Here the comparison of computed and "observed" quantities is made by the authors ($E.\ P.$) for meridians 40° apart.

By combining the probable errors of X_c, Y_c, and Z_c, the probable errors of the total force F_c are obtained.

The probable errors of H are determined from those of X and Y, whereas those for D (declination) and I (inclination), are formed directly from Fritsche's tables of residuals, of which Tables G give extracts.

We are now prepared to draw our conclusions. Beginning with

Digitized by Google

TABLE D. Mean probable errors of the computed components for 1842.5 and 1885.

[Expressed in units of fourth decimal, *C. G. S.*]

Parallel	I 1842.5			II 1885						III 1885					
	X	Y	Z	X			Y			Z			X	Y	Z
	F	F	F	NF	NS	FS	NF	NS	FS	NF	NS	FS	Mean	of F	and S
°															
N. 60	±23	±29	±43	±65	±33	±75	±19	±26	±29	± 107	±89	±48	±28	± 2	± 2
40	45	30	40	40	26	42	24	44	28	73	45	46	14	8	46
20	55	28	37	40	19	34	33	32	33	55	43	53	7	0	9
Equ'tr	90	30	39	36	22	35	36	33	40	31	40	36	26	8	10
20	62	23	59	32	20	25	19	17	24	46	30	28	10	0	1
40	30	27	40	35	20	30	39	32	40	46	70	76	8	15	20
S. 60	37	41	52	48	39	43	40	39	43	90	91	31	11	18	12
For Mean Parallel	±53	±30	±45	±44	±26	±43	±31	±33	±34	± 69	±63	±48	±17	±10	±20

TABLE E. Mean probable errors of the computed components for 1829 and 1830.

[Expressed in units of fourth decimal, *C. G. S.*]

Parallel	X		Y		Z	
	1830 G.	1829 E. P.	1830 G.	1829 E. P.	1830 G.	1829 E. P.
°						
N. 67	± 41	± 50	± 60	± 45	± 103	± 106
60	42	63	20	30	124	99
50	69	83	57	49	99	101
40	103	79	66	53	128	113
15	67	75	77	62	140	101
Equator	113	79	65	35	138	119
15	91	67	45	57	110	116
40	187	89	57	36	119	101
60	188	80	157	80	297	108
S. 75	148	74	211	75	368	57
For Mean Par'llel	± 117	± 75	± 99	± 56	± 183	± 102

TABLE F. Average probable errors of the computed elements for zone 60° N. to 60° S.

[The intensity quantities are given in units of fourth decimal, *C. G. S.*]

No.	Analyst.	Epoch	X	Y	Z	F	H	D	I
								°	°
1	Gauss	1830	±117	±99	±183	± 239	±153		
2	Erman-Petersen	1829	75	56	102	138	94		
3	Fritsche	1842.5	53	30	45	76	61	± 0.88	± 0.52
4	"	1885	44	31	69	87	54	0.92	0.66
5	Schmidt . .	1885	26	33	63	75.5	42		
6	Schmidt-Fritsche	1885	43	34	48	73	55		
7	Schmidt and Fritsche	1885	± 17	±10	± 20	± 28	± 20		

Digitized by Google

Table *F*, and leaving out of consideration, for the present, the entries Nos. 6 and 7, it will be noticed that the average probable error in the computed *X* component, for the entire zone of the Earth, 60° N. to 60 S., supposing the observed or chart quantities to be correct, has been steadily reduced until Schmidt's analysis (No. 5) gives a probable error of but $\frac{1}{8}$ of that of Gauss's, $\frac{1}{3}$ that of Erman-Petersen's, and $\frac{1}{2}$ that of Fritsche's for 1842.5. Looking at the probable errors for *Y*, we find for 1842.5, a value about $\frac{1}{3}$ that of Gauss, and $\frac{1}{2}$ that of Erman-Petersen, but since then there has been no reduction. The probable error for *Z*, for 1842.5 is about $\frac{1}{4}$ that of Gauss, and a little less than $\frac{1}{2}$ of Erman-Petersen's. Since 1842.5, there is an increase of about 50 per cent.

Examining next the probable errors for the total force, *F*, Fritsche's probable error for 1842.5, is about $\frac{1}{3}$ of Gauss's and $\frac{1}{2}$ of Erman-Petersen's. His 1885 probable error, however, in spite of the fact that this analysis was based on twice as many points, is about 15 per cent higher than the one for 1842.5. And what is certainly surprising, Schmidt's probable error, although his analysis was the most elaborate, painstaking, and comprehensive one up to date, dependent upon $4\frac{1}{2}$ times the number of points used by Fritsche for 1885, and 9 times the number used by Fritche for 1842.5, is the same as Fritsche's for the earlier epoch! As is well known, Schmidt not only took into account the spheroidal figure of the Earth, but also, for the first time, treated the three components *X*, *Y*, *Z*, separately, so as to avoid, *ab initio*, the assumption that the entire effect was to be ascribed to a potential due solely to internal forces. He obtained a small potential due to external forces and a system of vertical electric currents. His computed components are the combined effects of the three system of forces thus found.

We are apparently forced to conclude that the 1885 charts may not represent any improvement on those for 1840–1845. If this be true, then the explanation is to be found in the following statement: The additional material obtained since the construction of Sabine's charts, has been mostly in regions of which the *general* magnetic distribution, as given on a chart, was already fairly well-known. For the most important areas, such as ocean areas, but comparatively little material has been obtained. Sabine's charts were based on data distributed over about seven decades, the epoch 1840–1845 being about midway in this interval, so that the reductions to epoch, because of secular variation were partly positive and

Digitized by Google

TABLE G. Declination and inclination residuals for 1842.5 and 1885, according to Fritsche. ($D_o - D_c$ or $I_o - I_c$).

λ E of Gr	DECLINATION.														INCLINATION.												λ E of Gr
	60° N.		40° N.		20° N.		Equator.		20° S.		40° S.		60° S.		60° N.		40° N.		20° N.		Equator		20° S.		40° S.		60° S.		
	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	−1.3	+0.2	0.0	+1.1	−0.3	+1.8	−0.2	+1.1	−1.2	−0.4	+0.1	+0.3	−0.1	− 0.4	−0.3	−0.9	+0.5	+0.3	+1.7	−1.1	−0.2	−2.2	+0.4	−1.2	+0.7	+0.4	−0.2	−0.7	0
15		−0.9		−0.6		+0.2		+0.6		−0.2		−0.4		− 1.1		−1.4		0.0		−1.6		−2.2		+0.8		+1.5		−1.2	15
30	−0.5	−0.5	−1.4	−1.1	−1.0	−1.1	−0.4	−0.4	−0.8	−0.4	−0.9	−1.1	−1.8	− 0.7	−0.4	−1.4	+1.2	−0.6	−1.6	−1.1	−0.8	−1.9	−1.1	−0.1	−0.1	+1.5	−0.8	−0.8	30
45		0.0		−0.4		−1.1		−0.8		−0.5		−1.3		− 0.3		−1.2		−0.9		−0.7		−0.2		−0.8		+1.3		−0.7	45
60	+1.4	+1.0	−0.1	+0.6	−0.9	−0.7	−0.8	−0.3	+0.9	+0.2	+2.2	−0.7	+0.6	− 0.8	−0.8	−1.4	+0.5	−0.8		−0.8	+1.0	+0.2	+1.6	−0.6	+0.3	+1.0	−0.3	−0.5	60
75		+1.4		+1.2		−0.5		−0.5		−0.4		−0.8		− 2.6		−1.4		−1.0	+0.2	−1.1		+0.1		−0.2		+0.8		−1.0	75
90	+1.3	+0.3	−1.7	+1.7	−0.6	+0.2	−0.4	+0.2	−0.2	−0.3	−1.8	−0.3	−0.4	− 2.7	−0.1	−1.6	−0.4	−1.2		−0.7	+0.8	−1.4	+1.2	−1.3	+0.2	+1.0	−0.2	−1.1	90
105		−0.4		+0.6		+1.1		+0.9		+0.5		+0.3		+ 4.2		−1.8		−1.3	−0.4	−0.6		−0.7		−1.3		−1.2		−1.8	105
120	−1.7	+0.5	−1.5	−0.2	+0.1	+0.5	+0.3	+0.9	−0.5	+1.0	+0.5	+1.8	+9.1	+10.3	−0.1	−1.6	0.0	−0.8		+0.2	+0.8	−0.1	+1.5	−0.7	−0.4	+1.3	−0.7	−1.2	120
135		−0.4		−0.9		+0.2		+0.2		+0.5		+0.3		+ 6.6		−1.1		−0.4	−0.1	+0.6		+0.6		+0.1		+0.6		+0.3	135
150	+0.9	−0.4	−1.0	+0.1	−0.1	+0.3	−0.2	+0.3	+0.7	+0.1	+0.4	−1.2	−0.2	+ 0.1	−0.2	−1.1	+1.4	−1.0		−0.5	0.0	+0.3	+0.3	0.0	−0.4	+0.6	+0.4	+0.8	150
165		+0.7		+0.7		+0.2		+0.4		−0.4		−1.7		− 0.2		−1.0		−1.4	+0.3	−2.7		−0.2		+1.0		+0.1		+0.6	165
180	+3.3	+1.3	−0.2	+1.0	−0.2	−0.2	−0.9	+0.1	−0.7	−0.9	−0.3	−1.8	−2.0	− 1.6	−0.2	−1.2	−0.5	−1.5		−3.8	+3.1	−0.9	+3.3	+0.3	+0.1	−0.5	−0.4	+0.2	180
195		+0.4		−0.7		−0.9		−0.2		−0.6		−1.3		− 2.5		−0.8		−1.5	−1.4	−2.3		−0.5		+0.8		−0.2		−0.2	195
210	+0.8	−1.5	+0.8	−0.9	+0.5	−0.4	+1.3	−1.2	−0.3	−0.3	−0.5	−0.3	−2.9	− 3.1	+0.4	−0.5	−0.8	−1.5		−0.8	−1.0	−0.3	+0.2	−0.4	+0.4	−0.5	−0.2	−0.2	210
225		−2.5		−0.6		−0.2		−1.7		−0.2		−0.1		− 3.4		−0.5		−1.3	−0.2	+0.7		−0.5		−0.7		−0.2		−0.5	225
240	−0.7	−2.5	0.0	−0.6	−0.9	−0.8	−0.9	−2.1	+0.4	−0.3	−0.3	−0.9	−3.0	− 3.2	+0.2	−0.4	0.0	−0.4		−0.8	−0.2	−0.3	+0.5	+0.5	−0.1	−0.2	+0.6	−1.1	240
255		−3.4		+0.1		−1.0		−1.3		−0.5		−1.4		− 2.0		−0.6		−0.7	0.0	+0.1		−0.5		+1.0		−0.5		+0.1	255
270	−3.0	−3.5	+0.5	+0.1	+0.1	−0.7	−0.3	+0.1	+0.9	−0.3	+1.1	−0.5	+0.4	+ 1.2	−0.1	−0.7	+0.4	−0.9		−0.8	+0.6	+0.2	−0.4	+1.0	+0.4	−1.8	0.0	−0.2	270
285		+3.9		+0.5		−0.1		−0.6		−1.0		−0.9		+ 1.7		−0.3		−1.1	−0.4	−1.9		−0.5		−0.2		−0.5		−0.6	285
300	−1.3	+1.3	−1.4	+0.1	−0.4	+0.7	−0.8	−0.2	−0.8	−1.5	+0.2	−0.9	−1.3	+ 0.7	0.0	−0.2	+1.0	−0.6		−0.7	+0.5	−0.1	+2.6	−0.4	−0.4	0.0	+0.2	+1.0	300
315		0.0		+0.5		+0.7		+0.2		−0.6		−0.3		+ 0.3		−0.1		−0.2	−0.2	+0.4		+0.4		−0.8		−0.3		−1.3	315
330	+0.4	−0.5	+2.2	+0.3	+0.4	−1.1	+0.9	−1.6	+0.8	−0.2	+0.3	+0.5	+0.3	+ 0.4	−0.4	−0.2	−0.2	−0.1		+0.8	0.0	−0.3	0.0	+1.4	−0.1	−1.2	+0.9	+0.2	330
345		−0.5		+1.1		+1.1		−0.8		−0.5		+1.1		+ 0.1		−0.4		0.0	+0.4	+0.8		−0.5		+3.4		−0.6		−0.4	345
Mean	1.4	1.2	0.9	0.65	0.5	0.7	0.6	0.7	0.7	0.5	0.7	0.8	1.8	2.1	0.3	0.9	0.6	0.8	0.6	1.0	0.8	0.6	1.1	0.7	0.3	0.7	0.4	0.6	Mean
Prob. Error	±1.2	± 1.0	±0.8	± 0.5	±0.4	± 0.6	±0 5	± 0.6	±0.6	± 0.4	±0.6	± 0.7	±1.5	±1.8	±0 2	± 0.8	±0 5	± 0.7	±0.5	± 0.8	±0.7	± 0.5	±0.9	± 0.6	±0.2	± 0.6	±0.3	± 0.5	Prob. Error

Digitized by Google

partly negative, and thus the errors in reductions, to a certain extent eliminated. Neumayer, on the other hand, was obliged to depend entirely upon data accumulated up to the epoch 1885, his charts having been constructed in 1887. Hence, for large areas, he was forced to utilize data observed one-half century prior to his date and refer them to 1885, with more or less uncertain values of the secular change.

Another fact which leads one to conclude that in some manner an arbitrary or systematic error crept into the 1885 charts, due, possibly, to the reason stated, is the systematic variation in the probable errors with latitude. This will be noticed by looking over the X and Z figures in part II of Table D; it will be seen that the probable errors systematically increase with increasing latitude, whether we proceed north or south of the equator. This peculiar variation with latitude is not shown by the figures for either 1829, 1830, or 1842.5.

Let us pass next to the two bottom rows (Nos. 6 and 7) of Table F. Row No. 6 gives the probable errors resulting from the residuals between Schmidt's computed components and those of Fritsche. By glancing over the $S\,F$ residuals in Tables A, B, C, it will be seen that the results of the two computations often diverge more from each other than the results of either differs from the chart values, taken as standard of comparison. The average probable error of the total force resulting from these residuals is ± 73, hence, about the same as that of Schmidt's for 1885, and Fritsche's for 1842.5.

If we take as the computed components, the mean values of Schmidt's and Fritsche's computations, and compare the quantities thus derived with the chart values, then the residuals and probable errors will be materially reduced, as the two computations frequently diverge from the chart in opposite directions. See Part III, Table D, and row 7 of Table F. We now have probable errors about ten times those of field observations with modern instruments, and which probably represents the limit of accuracy attainable by a mathematical analysis based on general magnetic charts.

It is extremely unfortunate that we can not complete Table F, by including the probable errors resulting from the analyses of Adams for 1842.5, and for 1880. It is curious to note, by turning back to section a, Table V, that the value of the Earth's magnetic energy, as obtained from Adams' analysis for 1880, based upon Creak's charts, falls about midway between the values obtained

Digitized by Google

from the Fritsche and Schmidt's analyses. The mean value of the principal coefficient, g_{10} is 0.31684 as derived from the Fritsche–Schmidt analyses, or precisely equal to that of Adams's for 1880. So that the impression is awakened that Adams' computed components might be found to lie between those of Fritsche and Schmidt, and hence that the probable errors for Adams' analysis might be on the order of those in row 7, of Table *F*, or in any event, be smaller than either those of Fritsche or Schmidt. I trust to be able to look into this matter more fully at some future date. Adams did not compute the components.

Looking at the probable errors in declination and in inclination (rows 3 and 4 of Table *F*), for 1842 and 1885, we again note that there has been no improvement for the later date, although Fritsche based his later analysis upon twice the number of points used in the earlier one.[1]

Having now obtained a good idea of the magnitude of the residuals to be expected between the computed quantities and the values based upon general, or terrestrial magnetic charts, let us next make a comparison of the declinations derived from the Schmidt analysis for 1885, and those scaled from the recently published isogonic chart of the United States for 1902. On this chart the isogonic lines, while still to some extent generalized, were drawn to conform as nearly as possible, with the large mass of data utilized. Restricted local disturbances, could of course, not be represented, however, areal and regional disturbances manifest themselves in manifold sinuosities in the curves. The scaled values for 1902.0 were referred to 1885.0, with the aid of fairly well-known secular changes.

Table *H* gives the results of the comparison. The residuals range from 2′ to 3°03′; the average residual, regardless of sign is 86′ from which the probable error of $\pm$ 72′ is derived. Table I gives a comparison of the Schmidt and Fritsche residuals, at eighteen points in the United States. The *F* residuals are in general smaller than the *S* ones, and of opposite sign, except for latitude 50° N., where the *F* residuals are very large.

Tables *G*, *H*, *I*, show sufficiently, that in refined work, as, for

[1] Judging from a remark attributed to Professor Schuster, when my paper on the Earth's total magnetic energy, was presented before the recent meeting of the British Association, he, apparently, has likewise made the discovery that the uncertainty in the potential computation has not been decreased for 1885; he is said to have found the uncertainty to be less for 1842.

Digitized by Google

example, secular variation investigations, we can not, as has been proposed, make much use of the results obtained from a mathematical analysis. I shall have occasion to enter into this more fully in No. IV of these contributions.

TABLE H. Comparison of computed declinations according to Schmidt, and observed declination in the United States for 1885.

λ W. of Gr.	30° N.			35° N.			40° N.			45° N.			50° N.		
	D o	D c	D-D o c	D o	D c	D-D o c	D o	D c	D-D o c	D o	D c	D-D o c	D o	D c	D-D o c
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
65										−20 00	−17 39	−2 21			
70							−10 50	− 8 28	−2 22	−15 50	−13 19	−2 31			
75				− 3 20	− 1 58	−1 22	− 6 35	− 4 47	−1 48	−11 30	− 8 45	−2 45			
80	+ 1 25	+ 2 24	−0 59	− 0 10	+ 0 51	−1 01	− 2 05	− 1 15	−0 50	− 4 30	− 4 12	−0 18			
85	+ 4 05	+ 4 23	−0 18	+ 2 30	+ 3 22	−0 52	+ 2 20	+ 2 02	+0 18	+ 0 35	+ 0 12	+0 23	− 1 20	− 2 35	+1 15
90	+ 6 05	+ 6 03	+0 02	+ 6 15	+ 5 34	+0 41	+ 5 35	+ 5 01	+0 34	+ 5 50	+ 4 17	+1 33	+ 6 15	+ 3 12	+3 03
95	+ 7 50	+ 7 25	+0 25	+ 8 20	+ 7 30	+0 50	+ 9 45	+ 7 41	+2 04	+10 20	+ 8 00	+2 20	+11 30	+ 8 28	+3 02
100	+10 00	+ 8 33	+1 27	+11 00	+ 9 09	+1 51	+12 20	+10 02	+2 18	+13 40	+11 17	+2 23	+15 40	+13 04	+2 36
105	+11 00	+ 9 29	+1 31	+12 50	+10 35	+2 15	+14 30	+12 05	+2 25	+16 05	+14 07	+1 58	+19 20	+16 54	+2 26
110	+12 10	+10 15	+1 55	+14 00	+11 49	+2 11	+15 55	+13 52	+2 03	+18 25	+16 31	+1 54	+21 55	+20 01	+1 54
115	+11 45	+10 54	+0 51	+14 30	+12 53	+1 37	+16 50	+15 23	+1 27	+19 30	+18 29	+1 01	+23 45	+22 24	+1 21
120	+12 20	+11 28	+0 52	+15 20	+13 48	+1 32	+16 55	+16 38	+0 17	+20 10	+20 02	+0 08	+24 00	+24 07	−0 07
125							+17 45	+17 37	+0 08	+21 05	+21 09	−0 04	+24 10	+25 13	−1 03

TABLE I. Comparison of declination residuals resulting from subtracting computed declinations (Schmidt's and Fritsche's) from observed values in the United States for 1885.

λ W of Gr.	30° N.		35 N.		40° N.		45° N.		50°	
	S	F	S	F	S	F	S	F	S	F
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
75			−1 22	−0 01	−1 48	−0 10	−2 45	−0 45	+3 02	− 5 56
90	+ 0 02	−0 29	+0 41	−0 08	+0 34	−0 31	+1 33	+0 11	+1 54	+17 13
105	+ 1 31	−0 30	+2 15	−0 02	+ 2 25	−0 07	+1 58	−0 49	−1 03	+ 4 12
120	+ 0 52	−0 50	+1 32	−0 04	+0 17	−1 08	+0 08	−1 09		

The general conclusion to be drawn from the foregoing paragraphs, emphasizes once more,—as in section *a*—the absolute necessity of a new mathematical analysis, dependent upon a critical discussion and reduction of strictly homogeneous material.

TWO POINTS OF THEORETICAL INTEREST.

There may be two directions in which the Gaussian theory[1] will warrant modifications, in addition to those introduced by Schmidt.

First. The principal terms in the Gaussian analysis, arise from sufficiently deep-seated systems of forces, so that the magnetic per-

[1] What is meant by the Gaussian theory, and what physical facts it implies, are set forth in my article, *T. M.* Vol. V, p. 85.

Digitized by Google

meability of the medium or material intervening between the seat of the systems and the points of observation on the Earth's surface, may have to be taken into account if further refinement in the analysis is to be attempted. We shall then have the generalized Laplacian equation:

$$\frac{\partial}{\partial x}\left(\mu\frac{\partial V}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial V}{\partial y}\right)+\frac{\partial}{\partial Z}\left(\mu\frac{\partial V}{\partial z}\right)=0$$

in which μ is the magnetic permeability; it is no longer a constant as for the case treated in section *a*.

The magnetic distribution will now not be entirely harmonic.

Second. There is a possibility that there may be a minor system of forces so near the surface, that we can not any longer treat the points of observation on the Earth's surface, as though they were entirely outside the system of effective forces, so that the strict fulfillment of even the ordinary Laplacian equation—the fundamental property of a harmonic distribution—may not take place.

The detailed examination of these points must be reserved for the future.

Digitized by Google

BESCHREIBUNG DES NEUEN MAGNETISCHEN THEODOLITEN, "BAMBERG" NR. 7904, AM MAGNETISCHEN OBSERVATORIUM IN POLA.

VON K. u. K. CORVETEN-CAPITÄN W. KESSLITZ.

Die nachstehenden Figuren 2 und 4 stellen die beiden von einander unabhängigen Theile des Theodoliten, nämlich das Instrument zur Winkelmessung und den Apparat für die Bestimmung der Schwingungsdauer in perspectivischer Ansicht dar.

Das Instrument wurde von der Firma Carl Bamberg in Friedenau bei Berlin gebaut, wobei der Normal-Theodolit in Potsdam als Modell gedient hat und verschiedene Verbesserungen nach den Angaben des damaligen Leiters vom magnetischen Observatorium, Professor Dr. M. Eschenhagen, angebracht worden sind.

Leider hat Professor Eschenhagen die Finalisierung dieses Theodoliten nicht mehr erlebt. An dem herben Verlust, welchen das k. preussische meteorologische Institut durch das am 12. November 1901 erfolgte Hinscheiden dieses unermüdlichen Forschers erfahren hatte, nimmt auch das k. u. k. Hydrographische Amt, dem der Verblichene in erdmagnetischen Arbeiten stets ein treuer Rathgeber gewesen war, den wärmsten Antheil.

1. THEODOLIT FÜR DIE WINKELMESSUNGEN.

Das sehr solid gebaute und noch durch einem 4 *cm* hohen Messingreifen verstärkte Dreifuss-Stativ *D* (Fig. 1) ruht mit den 3 klemmbaren Stellschrauben auf dem am Pfeiler aufgegypsten Unterlagskreuz. Die säulenförmige Büchse *B* der Alhidaden-Achse *A*, welche die Unterlage des oberen drehbaren Theiles bildet, ist am centralen Ring des Dreifusses festgemacht. Im Hohlraume dieses Ringes, an der Achsenbüchse mit 6 Kopfschrauben befestigt, befindet sich der Messingkörper *M*, welcher oben eine cylindrische Ausnehmung für die Pfanne *p* besitzt. Letztere wird durch 2 Stifte *s* geführt und kann mittels der Schraube *T* mit ränderiertem Kopfe gehoben und gesenkt werden. Indem die Alhidaden-Achse *A* mit dem am unteren Ende befestigten, abgerundeten Stein *a* in einer Mulde der Pfanne *p* aufruht, wird durch entsprechendes Anziehen der Schraube *T* die Entlastung der Achse bewerkstelligt.

Die Schraubenmutter *m* bildet die Befestigung der Alhidaden-Achse in der Büchse; um erstere herauszuheben, muss vorerst die Schraubenmutter nach Abnahme des Messingkörpers *M* und der Pfanne *p* abgeschraubt werden.

Digitized by Google

Auf dem Ringansatz *r* der Achsenbüchse ist der Kreis *K* aufgesteckt, der sich aus 2 concentrischen, durch 6 Speichen verbundenen Ringen zusammensetzt. Indem der mit 4 Schrauben befestigte Deckring *d* den konisch geführten inneren Ring des Kreises nach unten presst, wird an der Berührungsfläche des letzteren genügend Reibung erzeugt, so dass eine Verdrehung des Kreises nur mit grösserem Kraftaufwande möglich ist.

Der silberne Limbus besitzt einen Durchmesser von 272 *mm* und ist von 5 zu 5′ getheilt. Eine zweite Theilung in halbe Grade befindet sich am inneren Rande des Kreisringes und dient zur Einstellung des Kreises auf den Index, der auf einem vom Deckringe *d* ausgehenden und bis zum äusseren Kreisringe reichenden Messingzeiger eingeritzt ist.

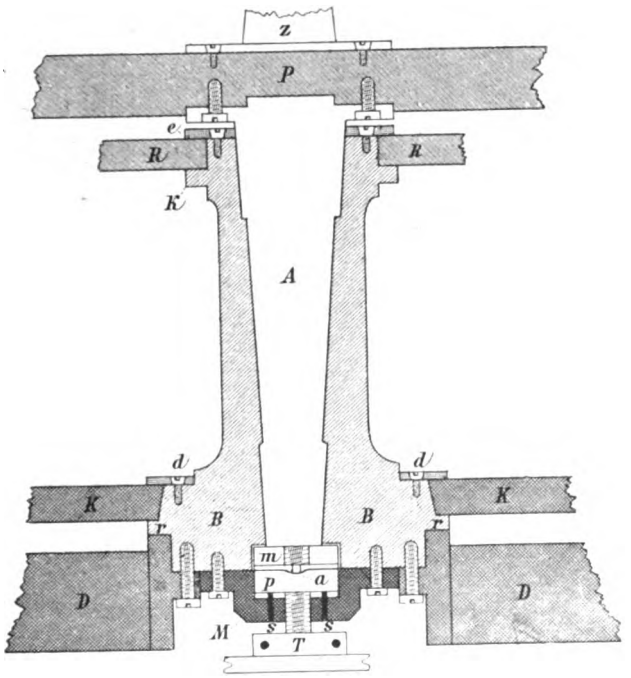


FIG. 1. (⅓ Natürliche Grösse.)

Am Ringansatz *k* der Achsenbüchse ist die Klemmplatte *R* mit der Klemmvorrichtung und der Mikrometer-Schraube sammt Federbüchse aufgesteckt und durch einen an der Büchse mit 4 Schrauben befestigten Deckringe niedergehalten. Diese Bestandtheile zeigen keine Abweichungen von den sonstigen Constructionen und ist deren Einrichtung aus Fig. 2 zu ersehen.

Das obere Ende des Achsen-Konus ist in die zum Theil durchbrochene,

Digitized by Google

im Centrum 22 *mm* dicke Alhidaden-Platte *P* eingelassen und dessen Ringverstärkung mit 6 Schrauben daran befestigt. Im Centrum der Alhidaden-Platte ist auf der Oberseite der konische Zapfen *Z* vom Magnetgehäuse festgemacht. Letzteres (Fig. 2) besitzt eine ähnliche Einrichtung wie beim neuen magnetischen Unifilar-Theodoliten von H. Wild[1] und besteht aus einem ringförmigen Gussstücke aus Messing, welches mit einer Hülse am centralen konischen Zapfen der Alhidaden-Platte aufgesteckt ist. Zur Orientierung des Gehäuses und der daran befestigten zweitheiligen Ablenkungsschiene ist am unteren Ende der Hülse ein drehbarer Ring angebracht, von dem ein Ansatz zwischen zwei auf der Alhidaden-Platte situierte Justier-Schrauben zu liegen kommt. Die Verbindung von Ring und Gehäuse wird durch eine Druckschraube bewerkstelligt. Ist letztere gelüftet, so lässt sich das Gehäuse beliebig verdrehen; nach bewirkter Klemmung des Ringes geschieht sodann die feine Einstellung mittels der auf der Alhidaden-Platte befindlichen 2 Justier-Schrauben.

Zum Schutze der eingehängten Magnete gegen Luftströmungen werden die cylindrischen Holzdeckel (in Fig. 2 abgenommen und am Dreifuss-Stativ angelehnt) mit den auf der Innenseite befindlichen 3 *mm* dicken Messingringen in das Gehäuse eingeschoben, wobei die rundlichen Ausnehmungen am Rande des äusseren schwachen Messingringes die cylindrischen Köpfe der Befestigungsschrauben passieren. Durch eine kleine Drehung kommt dann der äussere Ring unter die Schraubenköpfe zu liegen und wird auf diese Weise der Deckel festgehalten. In der Mitte der Deckel sind cylindrische Holzansätze angebracht, deren Öffnungen durch planparallele Glasplatten geschlossen sind.

Um die pendelnden Bewegungen des Magnet-, beziehungsweise Torsions-Stabes zu beruhigen, ist im Magnetgehäuse eine Petroleum-Dämpfung angebracht. Ein 15 *mm* hoher Napf von 30 *mm* Durchmesser ruht hiezu am cylindrischen Kopf eines federnden Stiftes, der durch einen Excenter gehoben oder gesenkt werden kann. Die Excenter-Welle lagert in einer Durchlochung der Alhidaden-Platte und befindet sich ihre Handhabe mit ränderiertem Kopfe auf der linken Seite des Fernrohrträgers. Die Hubhöhe des Excenters beträgt 4 *mm*. Zur Führung des federnden Stiftes dient eine oben cylindrisch ausgenommene Schraubenmutter, welche in den Gehäuseboden eingeschraubt ist.[2]

In den Petroleumnapf taucht ein kreuzförmiger Messingflügel mit kreisrunden Durchlochungen, welcher mit einem Doppelhaken am unteren Tragstift des Magnets oder Torsions-Stabes eingehängt wird.

In den zwei seitlichen Tubulaturen des Gehäuseringes sind die konisch zulaufenden und eingeschliffenen Enden der Ablenkungsschienen

[1] Mémoires de l'académie impériale des sciences de St. Pétersbourg. VII^e série, tome XXXVI, Nr. 1.

[2] Es hat sich vortheilhaft gezeigt, den Petroleumnapf ein- für allemal in einer bestimmten Höhe eingestellt zu belassen.

Digitized by Google

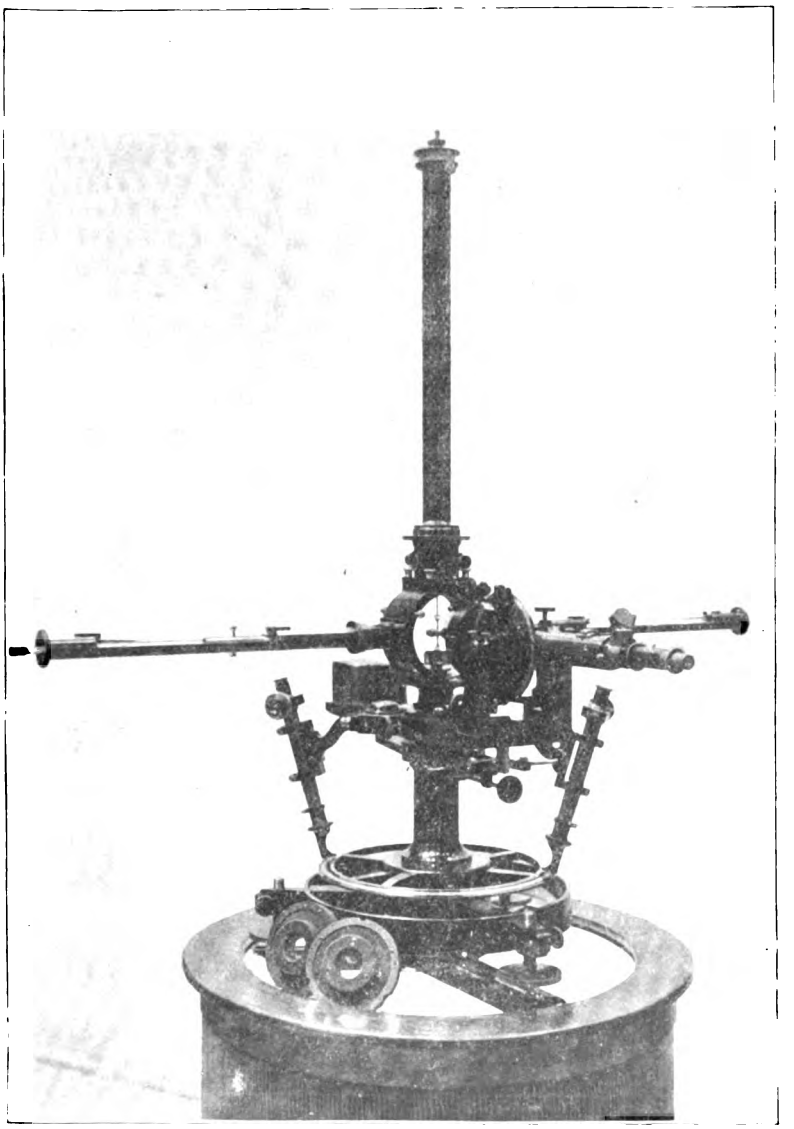


FIG. 2.

eingeschoben. Zur Erzielung einer unveränderlichen Stellung werden die Flanschen der Schienen mit den in Fig. 2 ersichtlichen grossen Schraubenmuttern an die oberen Ränder der Tubulaturen fest angepresst. Eine weitere Befestigung bewirkt noch eine Schraube mit versenktem

Digitized by Google

Kopfe, die, durch die Tubulatur hindurchgehend, mit ihrer konischen Spitze in eine gleichgeformte Aushöhlung des konischen Rohransatzes der Schienen eingreift.

Von den röhrenförmigen Schienen ist die obere Hälfte auf eine längere Strecke abgenommen, so dass eine im Querschnitt halbkreisförmige Rinne entsteht, in welche der ablenkende Magnet (Schwingungsmagnet) eingelegt wird. Der äussere Durchmesser des Magnets entspricht genau dem inneren der Röhre. Zur Einstellung desselben auf einen bestimmten Strich der Schienentheilung, die sich auf der einen, gegen das Fernrohr gewendeten Flachseite der Ausnehmung befindet, ist in der Mitte der Magnetröhre ringsum ein feiner Strich eingerissen. Die Einstellung geschieht mit der Hand bei Benützung einer Lupe. Zur Erleichterung des Einstellens bei einer fix angenommenen Ablenkungs-Distanz benützt man einen Anschlag, d. i. es wird der Magnet mit der einen Endfläche an den abgeschliffenen Kopf einer Schraube angeschoben, die in der Achse der Rinne in einem am Schienenrohr befestigten Messingwinkel klemmbar eingeschraubt ist. Die gleiche Einrichtung befindet sich am anderen Ende der Schienenausnehmung für die Beobachtung in der grösseren Distanz bei Bestimmung der sogenannten Ablenkungs-Constante.[2]

Zur Messung der Temperatur des Magnets wird ein in $\frac{1}{2}°$ getheiltes Thermometer in die Höhlung der Schiene gelegt und mit seinem cylindrischen Gefäss in den Magnet eingeschoben. Eine entsprechend weite Cartonröhre, die über die Schiene aufgestülpt wird, hat den Magnet vor der Wärmeausstrahlung des Beobachters zu schützen.

Auf der Oberseite besitzt der Gehäusering eine quadratische Verstärkung mit kreisförmiger Durchlochung, in welche der abgedrehte Fuss des Suspensions-Rohres bis zu der dem Gehäuseobertheil conform gestalteten Flansche eingeschoben und durch 4 Kopfschrauben befestigt wird.

Das Suspensions-Rohr setzt sich aus 3 Theilen zusammen, dem Klemmgehäuse, dem Fadenbehälter und dem Torsions-Kopf. Der 44 *cm* lange Fadenbehälter, ein Messingrohr von 35 *mm* Durchmesser, ist am Klemmgehäuse aufgeschraubt und durch eine seitlich in die Gewinde eingreifende Schraube gegen Verdrehungen versichert.

Die Klemmvorrichtung besteht aus der in Fig. 3 skizzierten Excenter-Scheibe *S*, welche auf die Stiftansätze *e* der Klemmplatten *K* einwirkt, und den seitlich im Klemmgehäuse angeschraubten Federbüchsen *F* für die Achsen *a* der Klemmplatten.

Die Bewegung der Excenter-Scheibe geschieht durch einen an der Verbindungsstelle zwischen Gehäuse und Fadenbehälter drehbar aufgesteckten, ränderierten Messingring, der mittels einer Schraube, welche

[2] Diese Anschlags-Einrichtung hat sich insoferne als illusorisch gezeigt, als die beiden Schwingungsmagnete nicht genau die gleiche Länge besitzen, daher bei jeder Bestimmung der Ablenkungswinkel die Anschlagschrauben verstellt werden müssen.

Digitized by Google

in einem Spalt des Gehäuses geführt wird, mit der Excenter-Scheibe in fester Verbindung steht. Durch ½ Umdrehung des Ringes nähern sich die Stiftansätze *e* und werden damit die Klemmplatten fest an den Rahmen *R* des Fadenbügels angedrückt. Bei der Rückdrehung kommen die in den Federbüchsen eingelagerten Spiralfedern, die sich einerseits an die Schraubenköpfe *k* am äusseren Achsenende, anderseits an den inneren Absatz der Führungshülsen *f* der Achsen stützen, zur Wirkung: die Achsen mit den daran befestigten Klemmplatten werden zurückgezogen und damit die Klemme geöffnet.

Um eine Verdrehung der Achsen und damit ein Heraustreten der Stifte aus der Excenter-Scheibe zu verhindern, besitzen die Achsen seitliche Dornansätze, welche in einer entsprechenden Nuth der Führungshülsen laufen. Die Achsen der Klemmplatten sind ferners der Länge nach durchbohrt und ist am äusseren Ende der einen Achse ein durchgehender Stift *t* angeschraubt, welcher, die breite Öse des Fadenbügels durchdringend, eine Verdrehung des letzteren zu verhindern hat.[1]

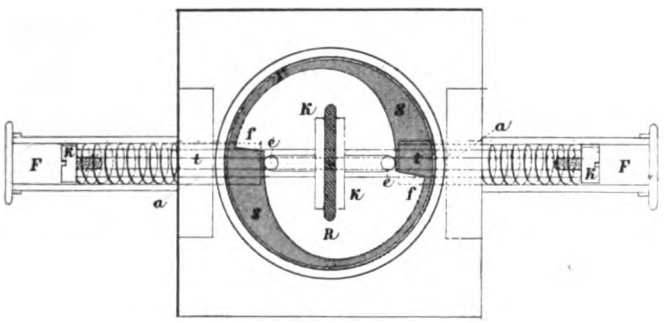


FIG. 3. (⅔ Natürlicher Grösse.)

Der Torsions-Kreis, welcher mit einem konischen Zapfen fest verbunden ist, besitzt eine Theilung von 5 zu 5°. Durch die centrale quadratische Durchlochung desselben geht der unten prismatisch geformte, oben mit Schraubenwindungen versehene Fadenträger hindurch, dessen verticale Verschiebung durch eine sich am Torsions-Kreis aufstützende Schraubenmutter mit ränderiertem Kopfe bewirkt wird. Der konische Zapfen ist in einem kurzen Cylinder eingepasst, der in das Suspensions-Rohr eingeschoben und durch einen Stift gegen seitliche Verdrehung gesichert wird. Zwischen dem oberen Ringansatz dieses Cylinders und dem Torsions-Kreis ist ein letzterem conform gestalteter Ring mit Index aufgelegt.

[1] Bei einem Theodoliten mit fixer Aufstellung scheint mir eine derart eingerichtete Klemmvorrichtung wohl gänzlich überflüssig, da der Faden auch ohne Klemmung durch ein entsprechendes Torsions-Gewicht stets in gleichmässiger Spannung erhalten werden kann.

Digitized by Google

Von den beiden seitlichen Arretierungs-Schrauben ist die mit ränderiertem Kopfe zur Fixierung des Torsions-Kreises bestimmt, indem die Spitze dieser Schraube in die Ringnuth des konischen Zapfens eindringt und angezogen auf letzteren drückt. Bei der zweiten Schraube ist die Tiefe des Eindringens in die Ringnuth durch einen cylindrischen Ansatz am Schraubenkopf begrenzt. Lehnt sich dieser Ansatz an das Suspensions-Rohr, so ist die Spitze der Schraube zwar auch in die Ringnuth eingetreten, berührt aber den Konus nicht. Es kann dann letzterer und damit auch der Torsions-Kreis zwar gedreht, nicht aber aus dem Suspensions-Rohre herausgezogen werden. Zur Befestigung des Metallfadens ist vom unteren Ende des prismatisch gestalteten Fadenträgers ein 10 *mm* langes Stück unter einem rechten Winkel herausgeschnitten und mittels Präcisions-Stift und Schräubchen befestigt. Der Faden wird zwischen diesen beiden Theilen des Trägers geklemmt und läuft dann durch eine schräge Durchlochung nach aussen, wo er an einem kleinen Schräubchen mit Unterlagsplättchen festgemacht ist. Eine gleiche Klemmung befindet sich am oberen Ende des Fadenbügels. Letzterer besitzt unter der Fadenklemme einen kreisrunden, abgedrehten Rahmen, der zwischen die Klemmplatten zu liegen kommt. Unten ist ein 63 *mm* langer Stift mit einem Doppelhaken zum Einhängen des Magnets angebracht.

Als Aufhängefaden für den Declinations- und Torsions-Stab, sowie für die abzulenkende Nadel dient, wie beim Normal-Theodoliten in Potsdam, ein 0.04 *mm* dicker Messingdraht.[1]

Auf dem einen Ende der länglich gestalteten Alhidaden-Platte ist der ⊔-förmige Fernrohrträger befestigt, am anderen Ende ein mit Blei ausgegossener Messing-Cylinder als Gegengewicht aufgeschraubt. In die senkrechten Arme des Fernrohrträgers sind die halbcylindrischen Lager der Achsenzapfen vom Fernrohr ausgeschliffen und letztere durch mit Kopfschrauben befestigte, gleichfalls ausgeschliffene Messingdeckel abgeschlossen. Am linken Achsenzapfen ist der Vertical-Kreis befestigt und die Nonius-Platte aufgesteckt, deren unterer Ansatz durch einen federnden Stift gegen die Spitze der Nonius-Rectificierschraube gedrückt wird. Die Theilung am Limbus des Vertical-Kreises geht auf halbe Grade, der Nonius ermöglicht eine Ablesung auf ganze Minuten. Der Träger für die Nonius-Lupe ist gleichfalls am linken Zapfen aufgesteckt.

Die Klemmvorrichtung des Fernrohres besteht aus einer Platte, deren unterer Ansatz zwischen der Mikrometer-Schraube und dem Stift der Federbüchse gelagert ist. Die Klemmschraube drückt von oben auf den Achsenzapfen und stellt, angezogen, eine feste Verbindung des Fernrohres mit der Klemmplatte her.

Da sich die Fernrohrachse ziemlich nahe dem Objectiv befindet, ist

[1] Das erdmagnetische Observatorium in Potsdam hat dem k. u. k. Hydrographischen Amte eine Rolle des dort benützten Messingdrahtes freundlichst zur Verfügung gestellt.

Digitized by Google

an der Fassung des letzteren ein cylindrisches Gegengewicht angebracht. Das Objectiv besitzt eine Öffnung von 32 *mm*. Das umlegbare Fernrohr ist terrestrisch eingerichtet und befindet sich die mit seitlichen Schrauben verstellbare Fadenplatte im Ocular-Auszug vor dem ersten Linsenpaar, also zwischen Objectiv und Ocular eingesetzt.

Unmittelbar hinter der Fadenplatte ist eine um 45° geneigte, planparallele Glasplatte eingesetzt, von der die untere Hälfte Spiegelbelag besitzt.[1] Zur Beleuchtung des Fadenkreuzes ist oberhalb der Glasplatte im Ocularrohr ein kreisrundes mit einer planparallelen Glasscheibe geschlossenes Loch ausgeschnitten und darüber ein universal drehbarer, runder Beleuchtungsspiegel angebracht.

Der Ocular-Auszug besitzt die sogenannte pankratische Einrichtung, d. h. es sind die das Ocular bildenden zwei Linsenpaare durch Einschaltung eines zweiten Auszuges sowohl gegen einander als auch zusammen gegen das Fadenkreuz verstellbar, wodurch innerhalb bestimmter Grenzen eine Variation der Vergrösserung zulässig ist.

Die Bewegung des ganzen Ocular-Auszuges geschieht mittels Welle und Zahnstange. Zur Führung der letzteren ist am Objectivrohr ein Plättchen mit rechteckigem Ausschnitt aufgeschraubt, in welchen die Zahnstange genau hineinpasst. Da die Schraubenlöcher im Plättchen länglich gestaltet sind, lässt sich die Zahnstange und damit auch der Ocular-Auszug sammt Fadenplatte behufs Justierung des Fadenkreuzes um ein Geringes verdrehen.

Die Ablesung der Alhidaden-Stellung geschieht mittelst Mikroskope, deren Träger, wie aus Figur 2 ersichtlich ist, an entsprechenden Ansätzen der Alhidaden-Platte festgeschraubt sind. Das Mikroskop *A* befindet sich rechts vom Fernrohr in einem Winkelabstand von 45°, ihm gegenüber ist das Mikroskop *B* angebracht. Jede Trommelumdrehung bewirkt eine Verschiebung des Doppelfadens um einen Theilstrich am Limbus, das sind 5′. Die rechteckig ausgeschnittene Blende besitzt in der Mitte einen zahnförmigen Einschnitt als Index. Da die Trommeleintheilung 100 Striche besitzt, können 5″ direct abgelesen und auf 1″ geschätzt werden. Zur Beleuchtung des Limbus sind zwar am Objectivende der Mikroskope Gipseinsätze drehbar angebracht, es wird jedoch eine scharfe Belichtung nur bei Anwendung eines kleinen Hohlspiegels erzielt, dessen Handhabung übrigens keinen nennenswerten Zeitverlust mit sich bringt.

Neben dem Träger vom Mikroskop *B* ist auf der Alhidaden-Platte eine kleine Dosenlibelle aufgeschraubt.

Die zu den Messungen dienenden Magnete, das sind der Declinations-Magnet, der kleine abzulenkende Magnet und die beiden gleichen Schwingungsmagnete I und II wurden aus Phönix-Wolfram-Stahl von

[1] Bei Einlieferung des Instrumentes hatte die Glasplatte keinen Spiegelbelag und gab deshalb nur sehr undeutliche reflectierte Bilder des Fadenkreuzes.

Digitized by Google

der Firma Joh. E. Bleckmann in Mürzzuschlag erzeugt und nach der Methode von Strouhal und Barus magnetisiert.

Sowohl der Declinations-Stab als auch die Schwingungsmagnete sind Röhren von 70.0 *mm* Länge, 10.5 *mm* äusseren und 6.5 *mm* inneren Durchmesser. Während bei den Schwingungsmagneten die Spiegel auf die ringförmige Endfläche am Nordende aufpoliert sind, wurde beim Declinations-Magnet ein runder, in einem kurzen Messingröhrchen gefasster Glasspiegel eingefügt und am Südende ein entsprechendes Gegengewicht angebracht.[2]

Das Gewicht der Schwingungsmagnete beträgt 29.15 *g*, jenes vom Declinations-Magnet 29.42 *g*.

Für das vorgenannte Dimensions-Verhältnis bei den Schwingungsmagneten hatte man sich deshalb entschieden, weil einerseits Professor Eschenhagen mir gegenüber die Dimensionen der Potsdamer-Magnete — nämlich Länge 75 *mm*, äusserer Durchmesser 16 *mm*, innerer Durchmesser 10 *mm* — für die Constanz des magnetischen Momentes nicht für zweckmässig bezeichnet hatte und anderseits mit dünneren Magnetröhren (Dimensions-Verhältnis 1:7) bei Reisetheodoliten sehr gute Erfolge erzielt worden waren.

Der abzulenkende Magnet mit Glasspiegel am Nordende ist eine Stahlröhre von gleichem Durchmesser wie bei den Schwingungsmagneten und hat eine Länge von 32.7 *mm*. Letztere beträgte somit 0.467 der Länge der Schwingungsmagnete. Durch die Wahl dieser Längen-Dimensionen wurde nach Wild der Bedingung entsprochen, dass das Glied q in der Gleichung für die sogenannte Ablenkungs-Constante verschwindet.

Als Torsions-Stab wird endlich ein cylindrischer Magnetstab benützt, welcher, von einer Messingröhre mit Spiegel am Nordende eingeschlossen, etwa $\frac{1}{3}$ des magnetischen Momentes vom Declinations-Magnet besitzt. Das Gewicht des Torsions-Stabes ist das gleiche wie jenes vom Declinations-Magnet.

Sowohl die Schwingungsmagnete als auch die abzulenkende Nadel besitzen auf der einen Seite die Buchstaben N und A, auf der anderen Seite B eingraviert. Das N befindet sich am Nordende der Röhre. Bei den Schwingungsmagneten ist noch die Bezeichnung I beziehungsweise II angebracht. Der Declinations- und Torsions-Stab besitzen zur Unterscheidung der beiden Spiegellagen die Bezeichnungen • und ••.

Zum Einhängen der Magnete in den Doppelhaken des Fadenbügels sind in der Mitte der Magnetröhre oben und unten je ein 10 *mm* langer T-förmiger Traghaken eingeschraubt, wobei der kurze horizontale Stift zur Magnetachse parallel gestellt ist.

[2] Die Anbringung eines Glasspiegels, beziehungsweise die Anwendung eines separaten Declinations-Magnets machte sich deshalb nothwendig, weil die angeschliffenen Spiegel der Schwingungsmagnete im Fernrohr des Theodoliten so schlechte Bilder vom Fadenkreuz gaben, dass eine scharfe Einstellung ganz unmöglich war.

Digitized by Google

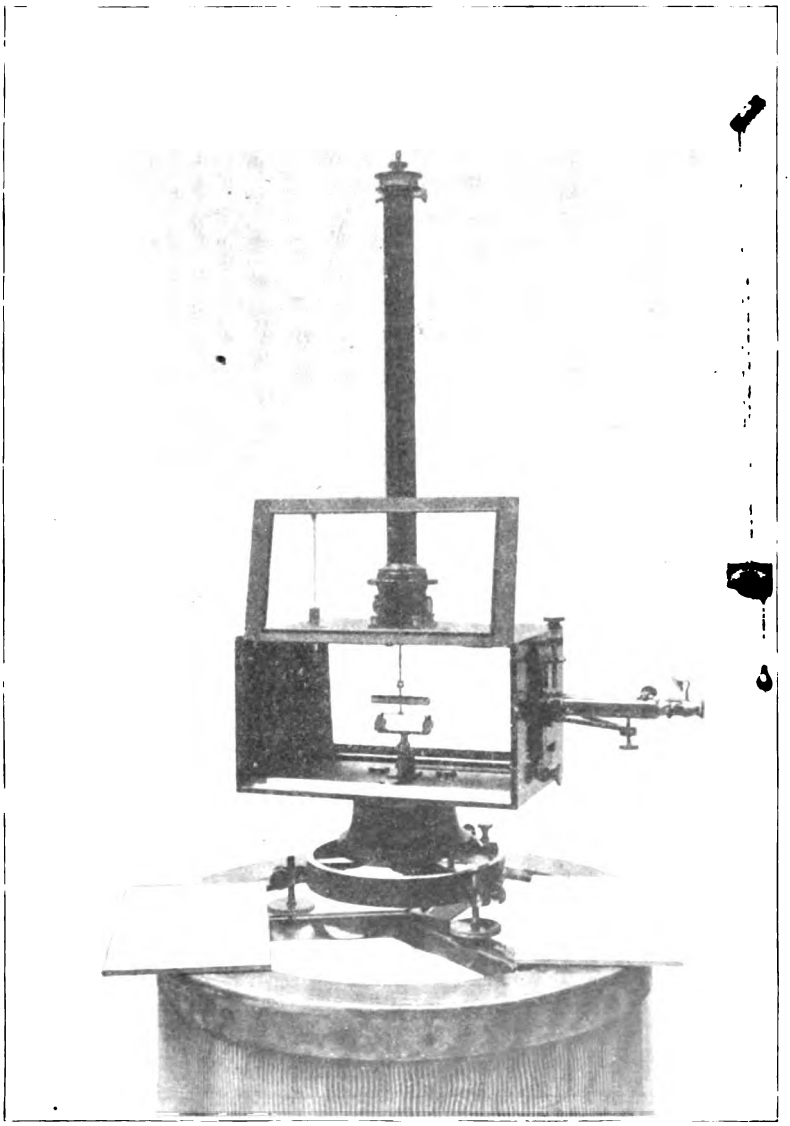


FIG. 4.

2. APPARAT ZUR BESTIMMUNG DER SCHWINGUNGSDAUER (FIG. 4).

Der Dreifuss mit den 3 klemmbaren Stellschrauben bildet mit dem 32 *mm* hohen Messingreifen, auf dessen abgedrehter Oberseite eine Eintheilung in halbe Grade eingerissen ist, ein Stück. In der konischen

Digitized by Google

Durchlochung des centralen Ringes ruht der Alhidaden-Zapfen und ist derselbe durch eine Schraubenmutter ohne weitere Entlastungsvorrichtung festgemacht. Die Alhidaden-Platte besitzt 3 Arme, von denen der eine den Nonius mit Theilung von 2 zu 2′, der zweite die Klemm- und Mikrometer-Vorrichtung trägt und der dritte auf einem gegen den Kreis abgeschrägten Ansatz nur mit einem einfachen Index-Strich versehen ist.[1]

Auf der Alhidaden-Platte ruht ein cylindrischer 7 *cm* hoher Holzklotz, die Unterlage des Schwingungskästchens. Die Befestigung des letzteren geschieht, mittels 3 Schraubbolzen, welche, durch den Holzklotz hindurchgesteckt, unten mit ihren Köpfen in die Alhidaden-Arme eingelassen sind, während an den oben herausragenden Enden die Schraubenmuttern und Unterlagsscheiben aufgesteckt sind. Das parallelpipedische Kästchen aus Mahagoniholz besitzt eine Länge von 32, eine Breite von 21 und eine Höhe von 17.5 *cm*. Die Seitenwände werden durch nach oben zu aufklappbare Charnier-Deckel mit Glasfenster gebildet. Ausserdem sind noch die in Falzleisten verschiebbaren, in Fig. 5 herausgezogen abgebildeten Holzdeckel angebracht.

Der Fuss des Suspensions-Rohres sammt Klemmgehäuse, welches die gleiche Einrichtung zeigt, wie jenes vom Theodoliten, ist in die kreisförmige Durchlochung der in der Mitte am Kastendeckel mit 4 Holzschrauben befestigten quadratischen Platte eingeschoben und dann in gleicher Weise wie beim Theodoliten mit 4 Kopfschrauben festgemacht.

Auf der vorderen Gehäusewand befindet sich ein Messingrahmen, in dessen schwalbenschwanzförmige Nut der Fernrohrschlitten mittelst der aus Fig. 5 ersichtlichen, verticalen Mikrometer-Schraube verschiebbar ist. Das Fernrohr mit 17 *mm* Objectiv-Öffnung besitzt im Ocular-Auszug ein Glas-Diaphragma mit eingeritzter Scala und der gewöhnlichen Beleuchtungsvorrichtung, nämlich ein hinter der Scala eingesetztes dreiseitiges Prisma und darüber ein universal drehbaren Spiegel.[2]

Durch das Prisma wird der obere Theil des Gesichtsfeldes verdunkelt und ist nur dessen untere Hälfte mit dem durchgehenden Mittelstrich durchsichtig. Da sich die Achsenzapfen des Fernrohres nahe bei der Objectiv-Öffnung befinden, ruht ersteres auf der Elevations-Schraube, mit welcher ein Heben und Senken des Ocular-Endes bewirkt wird.

In der Mitte des Kästchens befindet sichnoch ein als Arretiervorrichtung dienender Magnetträger. Das Heben und Senken der V-förmigen Lageransätze, die auf einer gemeinsamen rechteckigen Platte justierbar

[1] Ursprünglich war nur der Index-Strich (wie in Potsdam) vorhanden. Zur bequemeren Einstellung des Spiegelbildes und zur Winkelmessung bei Bestimmung des Torsions-Einflusses wurde nachträglich ein Nonius und die Mikrometer-Einrichtung vom Mechaniker Rost in Wien angefertigt.

[2] Wegen des directen Oberlichtes konnte der Beleuchtungsspiegel abgenommen werden. Die ursprünglich beigegebene Glasplatte hatte zu feine Striche und war daher das Spiegelbild sehr undeutlich, während das jetzt eingesetzte Diaphragma. ein Reservestück vom Theodolit Schneider, sehr gute Spiegelbilder liefert.

Digitized by Google

befestigt sind, geschieht durch die nahe dem Kastenboden eingesetzte Welle, deren Zahnrad in das untere, mit einer Zahnstange ausgerüstete Ende des Plattenträgers eingreift. Die Führung des letzteren geschieht durch eine am Kastenboden mittelst Schrauben befestigte Messinghülse.

Auf der vom Fernrohr abgewendeten Seite ist noch am Kastendeckel ein Messing-Tubus zum Hineinstecken des Thermometers eingesetzt. Der Fadenbügel besitzt bis auf die etwas längere ovale Schlinge die gleiche Einrichtung wie jener beim Theodoliten und dient zur Aufhängung des Magnets ein 0.05 *mm* dicker Messingdraht, dessen Torsionskraft durch mässiges Erwärmen mit Hilfe eines starken Batteriestromes erheblich herabgemindert wurde.

3. Verification des Instrumentes.[1]

Eisenfreiheit. Sämmtliche Bestandtheile des Theodoliten und des Apparates zur Bestimmung der Schwingungsdauer wurden auf das sorgfältigste auf Eisenfreiheit geprüft, indem man Stück für Stück in unmittelbare Nähe des Magnetgehäuses vom Unifilar brachte, während ein Gehilfe den Stand der Scala vom Magnetspiegel beobachtete. Hiebei constatierte man, dass sowohl die Suspensions-Rohre, als auch die Ablenkungsschienen einen geringen Eisengehalt aufweisen und somit vom Mechaniker der an ein magnetisches Normal-Instrument zu stellenden Hauptanforderung — nämlich absolute Eisenfreiheit — nicht mit der nöthigen Gewissenhaftigkeit nachgekommen worden war. Diesbezügliche Anfragen wurden von der Firma C. Bamberg dahin beantwortet, dass die in Rede stehenden Bestandtheile zwar aus vollkommen eisenfreiem Material erzeugt worden waren, aber nach der Bearbeitung auf der Drehbank einen geringen Eisengehalt angenommen hatten.

Spuren vom Eisengehalt sind ferner noch in den Bronzestäben zur Bestimmung der Trägheitsmomente der Schwingungsmagnete aufgefunden worden.

4. Apparat zur Bestimmung des Inductions-Coefficienten nach der Weber'schen Methode.

Der hiezu vom Mechaniker Töpfer in Postdam construierte Apparat besteht aus einem 19 *cm* langen, mit circa 17 Lagen übersponnenen Kupferdraht von 0.25 *mm* Stärke umwickelten Messingrohr, welches in der aus Fig. 5 ersichtlichen Weise derart auf dem ⊔-förmigen Träger aufmontiert ist, dass mittelst einer Kurbel eine Drehung um die Horizontal-Achse ausgeführt werden kann.

Durch entsprechende Anschläge wird die Drehung der Spule auf genau 180° begrenzt. Die Achsenträger und die gemeinschaftliche Fussplatte sind auf einem gewöhnlichen Dreifuss-Stativ drehbar befestigt. Auf der Fussplatte kann eine Dosenlibelle oder eine Bussole zur Nivellierung, beziehungsweise Orientierung des Apparats aufgesteckt werden.

[1] For method of adjustment of instrument and report on determination of constants, see "Jahrbuch" Pola Observatory for 1902.—Ed.

Digitized by Google

Die Drahtenden der Spule laufen von der Mitte aus durch den einen hohlen Achsenzapfen nach aussen zu den Klemmschrauben auf der Fussplatte. Die Umwicklung besitzt einen Widerstand von 121 Ohm.

Zur Bestimmung des Inductions-Coefficienten wurde das Instrument zunächst derart orientiert, dass die Vertical-Ebene, in welcher die Drehung der Spule erfolgt, mit dem magnetischen Meridian einen rechten Winkel bildete. Nach Anschliessung des hochempfindlichen Rosen-

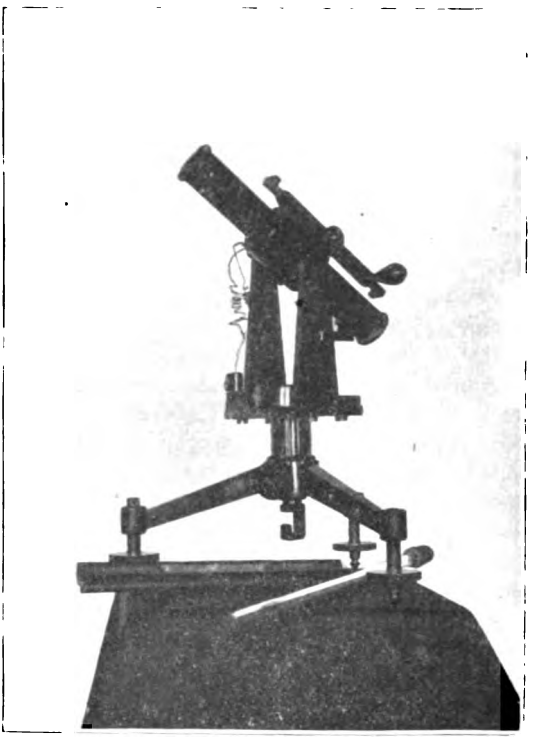


FIG. 5.

thal'schen Galvanometers, welches für die Inclinations-Bestimmungen benützt wird, wurde zuerst die Spule allein (10mal) und dann die Spule mit dem genau centrierten Magnet (40mal) um 180° gedreht.[1] Die Richtung der Drehung liess man hiebei abwechseln und wurde auch der Magnet in der Holzfassung umgelegt.

[1] Zur Centrierung des Magnets diente ein zweitheiliger, in die Spule genau hineinpassender Holz-Cylinder, in dessen Mitte eine den Dimensionen des Magnets entsprechende Ausnehmung ausgedreht worden war.

Digitized by Google

Behufs Auswertung stellte man sodann die Spule vertical, schob ein 47 *cm* langes, in einem Holzpfropf eingepasstes Glasrohr,[1] welches unten abgeschlossen war, bis zur Hälfte in die Spule und liess einen kleinen Magnet von bekanntem Moment aus einer Höhe von 35 *cm* in die Glasröhre hineinfallen, beziehungsweise rasch herausziehen.

Vergleicht man die mit diesem Apparate erhaltenen Werte von k mit jenen nach der Methode von Lamont gefundenen, so zeigt sich eine überraschend gute Übereinstimmung und wurde daher ohne Bedenken das Mittel der so nach verschiedenen Methoden abgeleiteten Coefficienten für die Berechnung der Inductions-Correction verwendet:

	Magnet I	Magnet II
Inductions-Coefficient nach Lamont:	0.00957	0.00998
„ „ „ Weber:	0.00954	0.00992
Mittel:	0.00956	0.00995

[1] In Fig. 5 befindet sich das Glasrohr unter dem Stativ neben der rechten Stellschraube.

Digitized by Google

THE LUNAR DIURNAL VARIATION AS OBTAINED AT THE CHELTENHAM MAGNETIC OBSERVATORY FROM A SINGLE COMPLETE LUNATION DURING FEBRUARY, 1903.[1]

By L. A. Bauer and R. E. Nyswander.

(Abstract.)

The attempt was made to determine how well the lunar diurnal variation of the magnetic elements could be determined from simply one complete lunation, instead of using records extending over a period of a year or more.

For this purpose the comparatively "magnetically calm" month of February, 1903, was selected and the photographic records obtained at the Cheltenham Magnetic Observatory of the Coast and Geodetic Survey with an Eschenhagen Magnetograph were utilized. The scale values used were: 1 mm. ordinate, declination = 1.014 minute,

1 mm. " horizontal intensity = 0.00002 C. G. S. unit.

The recently arrived vertical intensity instrument was not yet in satisfactory adjustment and hence the records could not be successfully used.

First the declination ordinates were read off at the actual lunar hours as marked on the magnetograms, for the entire lunation beginning on February 1, 1903, and tabulated in the same manner as are the solar ordinates for a calendar month. On February 7th occurred a disturbance of sufficient amount to require elimination. In place of the actually observed ordinates, the means of the corresponding hours of the two days between which the disturbance occurred were substituted. The mean ordinates for each lunar hour for the entire lunation were next derived and the residuals on the mean of all the ordinates formed; these residuals being freed by this process from the effect of the solar diurnal variation, since the same solar hour fell successively on each lunar hour, were expected to exhibit the lunar diurnal variation in the declination. How well they do so, is seen by an inspection of the curve drawn in full, Fig. 1. The double oscillation in twenty-four hours, with the turning points about six hours apart, is well brought out. The average range between maximum and minimum is about 67″, two to four times larger than usually found by combining the results for several years.

Next, the declination ordinates as scaled for the solar hours were

[1] The diagrams were on exhibition at the recent meeting of the International Meteorological Conference held at Southport, England.

The Abstract is published with the permission of the Superintendent of the Coast and Geodetic Survey. The complete publication is deferred until the investigation has been extended over several lunations.

Digitized by Google

tabulated according to lunar hours, by merely taking the hourly solar ordinate nearest to the particular lunar hour, or in case the lunar hour fell nearly midway between two solar hours, the mean of the two solar ordinates was taken. This was done for the entire lunation and the residuals again formed as before, with the results as exhibited in the broken curve of Fig. 1. There is practically no difference between this curve and the previous one. Hence, if magnetograph observations

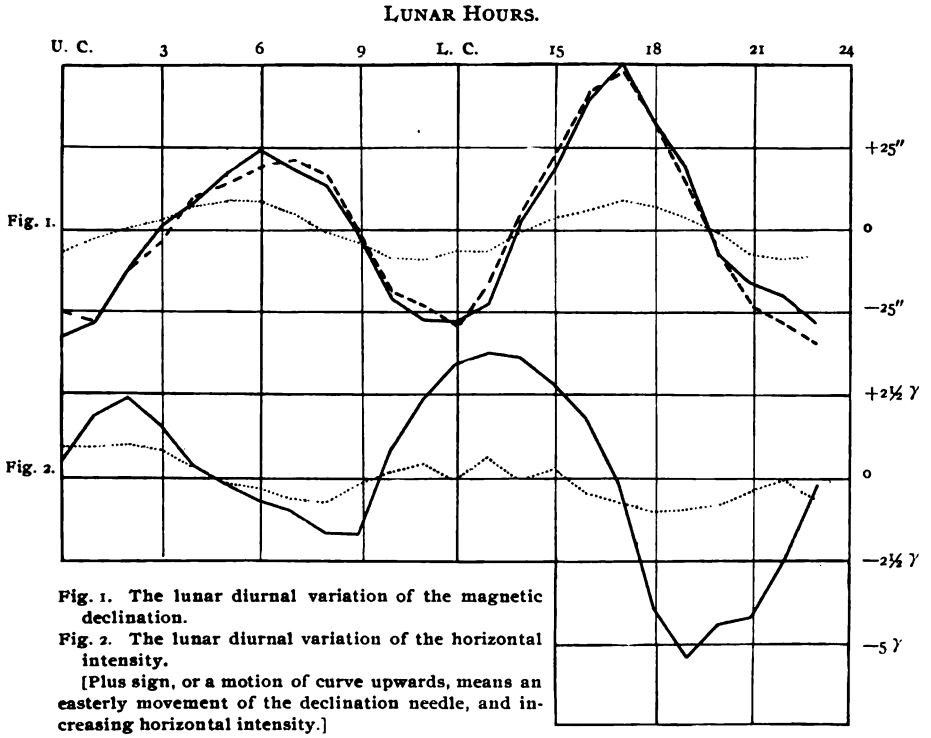


Fig. 1. The lunar diurnal variation of the magnetic declination.
Fig. 2. The lunar diurnal variation of the horizontal intensity.
[Plus sign, or a motion of curve upwards, means an easterly movement of the declination needle, and increasing horizontal intensity.]

possess the desired degree of accuracy, and disturbances are eliminated, the lunar diurnal variation can be obtained expeditiously and with sufficient accuracy from the usually published solar ordinates for each lunation separately, and thus an annual inequality of this interesting variation can be successfully investigated.

The dotted curve Fig. 1 exhibits the mean lunar diurnal variation of the declination as obtained at the Los Angeles[1] Magnetic Observatory during the three years October, 1882–October, 1883; October, 1885–Octo-

[1] Los Angeles, California. This observatory was operated by the U. S. Coast and Geodetic Survey, between 1882 and 1889, the magnetograph being of the old Adie pattern.

Digitized by Google

ber, 1886, and October, 1888-1889; the period includes a year of maximum sun spot activity and a year of minimum sun spot activity.

The lunar diurnal variation in the horizontal intensity, as shown by the full curve, Fig. 2, was obtained from the solar hourly ordinates for the complete lunation in same manner as the second declination curve. No corrections for temperature changes were required, as on account of the means employed at this observatory, the temperature was so uniform as to make the corrections negligble. The double oscillation is again most satisfactorily shown. The average range between maximum and minimum is about 6.6 gammas (0.000066 C. G. S. unit.)

The mean result of the same three years of observations at Los Angeles, as for the declination, obtained with less refined instruments, is shown by the dotted curve, Fig. 2.

The vector diagram combining the changes in declination and horizontal intensity for the single lunation was also drawn and found to consist of a curve of two loops of unequal area.

In view of the success achieved within a limited period, there ought to be no reason now for observatories not publishing lunar diurnal variation results as well as those of the solar diurnal variation.

Digitized by Google

SECOND INTERNATIONAL SEISMOLOGICAL CONFERENCE AT STRASSBURG.

HARRY FIELDING REID.[1]

In response to a call from the German Government, delegates were appointed by various countries to meet in Strassburg, from July 24th to 28th of the present year, to discuss the organization of an International Seismological Association. Official delegates were present from the following nineteen countries, namely: Germany, Argentine Republic, Austria, Belgium, Bulgaria, Chili, Congo, United States, Great Britain, Hungary, Japan, Italy, Mexico, Holland, Portugal, Roumania, Russia, Sweden, and Switzerland. France and Spain also had representatives, but they did not come as official delegates.

The meetings took place in the main assembly-room of the "Landesausschussgebäude," and were opened by the Prince of Hohenlohe-Langenburg, Imperial Governor of Alsace-Lorraine. He made an address of welcome to the delegates, and was followed by Professor Dr. Gerland, the director of the Imperial Central Seismological Station at Strassburg, who also welcomed the delegates and stated the object of the meeting.

The meetings for the discussion of the organization of the Association and of scientific questions, took place morning and afternoon. German, French, English, and Italian, were all used in the discussion, but the motions were translated into both French and German before they were voted.

The delegates, although officially sent by their respective governments, came as a rule, without special authority, and only acted an advisory part. The result of the deliberations was to decide upon a form of organization for an International Seismological Association. This will be submitted to all civilized nations by the State department of the German Government, and they will be invited to join the Association.

The important parts of the constitution are as follows:

The object of the Association is the study of seismological problems, whose solution is only possible by the co-operation of many observatories in all parts of the world. The principal means of attaining this object are:

a. Observations according to common principles;

b. Experiments on problems of special importance;

c. Foundation and support of seismological observatories in countries which need the pecuniary aid of the Association;

[1] Professor Reid was the official delegate from the United States.—ED.

Digitized by Google

d. Organization of a Central Bureau for the collection, study, editing, and publication of the reports sent from various countries.

The members of the Association shall be the nations which may join. They are to make the following annual contributions through the department of State at Berlin:

a. Nations with a population of less than five million, $100.

b. Nations with a population between five and ten million, $200.

c. Nations with a population between ten and twenty millions, $400.

d. Nations with a population of more than twenty million, $800.

The organs of the Association are:

a. The General Assemby;

b. The Permanent Commission, and

c. The Central Bureau.

The General Assembly shall consist of delegates from the Nations which are members of the Association, and is to meet at least once in four years. Delegates from scientific societies and other persons, may be invited to attend the General Assembly.

The Permanent Commission shall consist of the Director of the Central Bureau and one delegate from each Nation.

It shall elect from its own number its President, Vice-President, and Secretary-General.

The Permanent Commission shall have general control of the affairs of the Association, and shall see that the resolutions of the General Assembly are carried out. It shall also direct the method of expenditure of the funds of the Association, which are to be used for:

a. Expenses of publication and administration;

b. Salary of the Secretary-General;

c. To subsidize theoretical work or experiments of exceptional importance which may have been ordered by the General Assembly.

d. For the foundation and support of seismological observatories founded by the Association, the observations of which are of general interest for the study of seismical phenomena.

A financial account shall be published in the proceedings of the Permanent Commission.

The Central Bureau shall be located at the Imperial Central Seismological Station at Strassburg, and the director of the latter shall be the director of the Central Bureau; the Central Bureau shall have the benefit of the assistants and resources of the Central Station.

The Central Bureau shall collect the reports from the different countries, edit and publish them. The director of the Central Bureau shall present an annual report covering the whole work of the Bureau, and shall also outline the work proposed for the following year.

The secretary-general shall make a report to every General Assembly on the work and condition of the Association. He shall attend to the

Digitized by Google

publication of the proceedings of the Permanent Commission, of the deliberations of the General Assembly, and of investigations undertaken by order of the Association. He shall have charge of the general affairs of the Association under the direction of the President of the Permanent Commission.

The Association shall be formed for a period of twelve years, beginning April 1, 1904. Nations which join the Association may withdraw at the end of each period of four years, on giving six months' notice of their intention.

The various articles of this constitution were carefully debated, and, indeed, this took up the larger part of the time of the convention. It is not intended for the present, at least, to outline the "common principles" according to which observations should be made, but each Nation and observer is to be allowed the largest liberty in this respect. It was, however, unanimously decided that in the reports of earthquakes, Greenwich mean civil time should be used. A new scale of intensities for earthquakes was proposed, but it was decided that it was not advisable for the Association to adopt for the present any definite scale.

Some delegates wished the Association to give advice with respect to the best instruments to be adopted by observatories taking up this work, but it was decided that the Association was not prepared to give this advice, and that each observatory should select for itself the instruments which seemed best adapted to its purpose. A committee, however, was appointed to draw up an account of the various instruments now in use.

A number of scientific papers were read on various subjects connected with seismology, but in general, there was not sufficient time for a full discussion of their contents.

Under the direction of Professor Gerland and his able assistants, a visit was made to the Central Seismological Station, at Strassburg, to see the various instruments which are there recording, and to see the general arrangements of the building. An instrument which attracted much attention, was a newly made inverted pendulum of Professor Wiechert, of Göttingen, having a weight of 2000 kilograms and recording on smoked paper. The recording point magnifies the movement of the pendulum two hundred times.

The delegates were entertained most hospitably in Strassburg. The Prince of Hohenlohe-Langenburg gave a dinner in their honor, as did also the mayor of the city: and a very interesting excursion to the Vosges Mountains was made on Sunday, July 26th; a subscription dinner completed the social functions. The delegates were greatly pleased with their visit to Straussburg, and appreciated highly the courtesy shown them by all who took part in the arrangements for the meetings.

Johns Hopkins University, Baltimore, Maryland.

Digitized by Google

STEPHEN JOSEPH PERRY, S. J., F. R. S.

Stephen Joseph Perry was born at London, August 26, 1833, of Catholic parents. His education covered a period of over nineteen years, about eight of which were passed at school at Gifford Hall, and at the Benedictine College at Douay; five more were spent at Rome, St. Acheul, and Stonyhurst, and two under De Morgan in London and Bertrand, Lionville, Delaunay, Cauchy, and Serret in Paris. Having entered the Society of Jesus in 1853, he studied theology the remaining four years as a preparation for the priesthood.

In 1860, he was called to Stonyhurst College as Professor of Physics and Mathematics, and to take charge of the Observatory, which, founded in 1838, primarily as a meteorological station, had begun under his predecessor, Father Weld, to establish a reputation for itself in meteorology and terrestrial magnetism. In that same year, 1860, was issued the first annual report in the form of a neat volume, in which were tabulated the mean results of the readings of the thermometers, barometers, rain-gauge and wind-gauge. He remained at Stonyhurst two years, leaving to enter St. Beuno's College, where he prepared himself in theology, as before mentioned.

In 1866, he entered the priesthood, after three years' probation in which, he resumed his original duties at Stonyhurst, where, with the exception of journeys undertaken in the interests of science, he remained until the last expedition, which proved fatal to him. He died at sea off the coast of French Guiana, December 27, 1889, and was buried at Demarara.

While Director of Stonyhurst Observatory, Father Perry greatly extended the work in the three branches of science taken up there—meteorology, terrestrial magnetism, and astronomy. To speak especially of terrestrial magnetism, besides the regular routine work of a magnetic observatory, special attention was paid to magnetic storms, auroræ and earthquakes, and several magnetic surveys were undertaken. These were surveys, in conjunction with Father W. Sidgreaves, of the west of France and of the east of France, and one of Belgium, in which he was assisted by Mr. W. Carlisle. In the course of some of his scientific voyages, Father Perry also determined the magnetic elements at the Cape of Good Hope, Kerguelen, Bombay, Aden, Port Said, Malta, Palermo, Rome, Naples, Florence, and Moncalieri, and at Nos Vey, Madagascar. These scientific voyages comprised, two to observe the Transit of Venus, and four to make observations of total solar eclipses. The last one he took part in was to the Salut Isles, off the coast of French Guiana, to observe

Digitized by Google

the solar eclipse of 1889. He contracted in that unhealthy climate the fever which resulted in his death.

Besides being an able director, Father Perry was a gifted lecturer. Among his most important lectures were those delivered before the Royal Institution on the Transit of Venus and the Solar Surface; those before the Société Scientifique of Brussels, and the Catholic Scientific Congress at Paris; and at Montreal, in connection with the meeting of the British Association.

He was elected Fellow of the Royal Society in 1874, and was also a Fellow of the Royal Astronomical Society, and of the Royal Meteorological Society. Of societies outside of Great Britian, he was an Associate of the Pope's Academy of the Nuovo Lincei, the oldest established scientific society in Europe, as also of the Société Scientifique of Brussels, and the Société Geographique of Antwerp. In 1866, he received the honorary degree of D. Sc. from the University of Ireland. He served on several important scientific committees.

Besides the valuable reports of the Stonyhurst Observatory, he was the author of numerous articles in "Nature," and many papers by him are found also in the Proceedings of the Royal Society, and of the Royal Astronomical Society, and elsewhere.

Father Perry's aim, in all his scientific work was, to use his own words, "not to undertake any work that would be a mere repetition of what was being done better elsewhere."[1]

[1] The portrait of Father Perry was furnished by Father Sidgreaves, whereas the the biographical sketch is taken largely from Father Cortie's "Life of Perry," a copy of which was supplied to the Editor by Father Hagen.

Digitized by Google

RECENT PUBLICATIONS

ASTRONOMER ROYAL. Mean daily area of sun-spots for each degree of solar latitude for each year from 1874 to 1902, as measured on photographs at the Royal Observatory, Greenwich. Monthly Notices Royal Ast. Soc. 1903,
Vol. LXIII, pp 452–461.

BIGELOW, F. H. Studies on the meteorological effects in the United States of the solar and terrestrial physical processes. [Washington, 1903. 4°. Repr. Monthly Weather Review, 1902.

COLIN, P. Travaux astronomiques et magnétiques à Madagascar. Extrait Comptes Rendus CXXXVI, p. 1298, séance du 2 juin 1893. [For abstract see Dec. issue of T. M.]

CONRAD, V. Beiträge zur Kenntnis der atmosphärischen Electrizität. VIII Über die entladende Wirkung verschiedner Elektroden. Wien 1902 8°. 8 pp. Repr. Sitzungsb. d. Wiener Ak., mat.-naturw. Kl., Bd. CXI. Einige Bemerkungen zur Wolkenelektrizität. 8°. 4 pp. Repr. idem Bd. CXI.

CONARD, V. AND EXNER, F. M. Beiträge z. Kenntnis der atmosph. Elektricität. XII. Registrierungen des luftelektrischen Potentials anf dem Sonnblick. Wien 1903. 8°. 7 pp. Repr. Sitzungsb. d. Wiener Ak., mat.-naturw. Kl. Bd. CXII.

EXNER, FELIX M. Zur Theorie der verticalen Luftströmungen. Wien. K. Gerold 1903. 8°. 25 pp. Repr. Sitzb. d. Wiener Acad. math.-naturw. Kl. Volume CXII, Abt. IIa.

LOCKYER, N. & LOCKYER, W. J. S. The relations between solar prominences and terrestrial magnetism. Proc. Roy. Soc.
Volume LXXI, pp. 244–250, 1903.

NORDMANN, C. J. 1re Thése. Essai sur le rôle des ondes Hertziennes en Astronomie Physique et sur diverses questions qui s'y rattachent.
2e Thése. Propositions données par la Faculté.
[Thèses presentées a la Faculté des Sciences de Paris. Paris, 1903.]

SAAKE, W. Messungen des electrischen Potentialgefälles, der Electrizitätszerstreuung und der Radioactivität der Luft im Hochtal von Arosa (Schweiz). 4°6 Repr. Physikal. Zeitschr., 4. Jahrg. Nr. 23, 1903.

SOUTHERN CROSS ANTARCTIC EXPEDITION, 1898–1900. Magnetic and Meteorological observations made under the direction of *C. E. Borchgrevink*. London (Roy. Soc.) 1902, 4°. 1 plate.

Digitized by Google

ASTOR, LENOX AND
TILDEN FOUNDATIONS.

Digitized by Google

OBSERVATORIO MAGNETICO Y METEOROLOGICO DE LA ISLA DE "AÑO NUEVO."

Digitized by Google

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VIII DECEMBER, 1903 NUMBER 4

THE DIURNAL FIELD OF MAGNETIC DISTURBANCE.[1]

By Dr. W. van Bemmelen.

It has been known for some time that the Earth's magnetic force on days of disturbance shows a characteristic change, both in amount and direction, from the normal value as derived from quiet days. In 1895[2] the author inquired into this phenomenon by the method briefly described below.

Let h_s, d_s, v_s; h_1, d_1, v_1; h_2, d_2, v_2; h_3, d_3, v_3, etc., represent, respectively, the daily means of horizontal intensity, declination, and vertical intensity, on a day of disturbance and subsequent quiet days. For a number of n cases were computed the mean values:

$$H_s = \frac{h_{1.s} + h_{2.s} + \cdots h_{n.s}}{n}, \quad D_s = \frac{d_{1.s} + d_{2.s} + \cdots d_{n.s}}{n},$$

$$V_s = \frac{v_{1.s} + v_{2.s} + \cdots v_{n.s}}{n};$$

$$H_1 = \frac{h_{1.1} + h_{2.1} + \cdots h_{n.1}}{n}, \quad D_1 = \frac{d_{1.1} + d_{2.1} + \cdots d_{n.1}}{n},$$

$$V_1 = \frac{v_{1.1} + v_{2.1} + \cdots v_{n.1}}{n};$$

$H_2 =$ etc.

The values $(H_s - H_m)$ and $H(D_s - D_m)$, H being the mean value of the horizontal intensity, determine, with sufficient accuracy for the purpose, the horizontal component of the average dif

[1] Presented to the Royal Academy of Sciences at Amsterdam, October, 1903.
[2] *Meteorol. Zeitschr.* 1895, p. 321.

Digitized by Google

ferential vector for the days of disturbance and the m following days. The angle α determined by $\tan \alpha = \frac{H(D_s - D_m)}{H_s - H_m}$ is the magnetic azimuth of the differential vector, which we may call the disturbing vector.

A first result of these calculations was found to be that this angle α is fairly constant for any one station; a second result, derived from a consideration of this azimuth for twenty-eight stations distributed over the Earth, was that, generally speaking, this disturbing vector is directed perpendicularly to the isochasms (lines of equal frequency of aurora polaris), pointing away from the pole of the aurora borealis.

As we can always suppose that the magnetic force is caused by an electric current directed perpendicularly to the vector, this result led to the hypothesis of a system of electric currents circulating around the Earth parallel to the isochasms, the strength of the current being increased during disturbance, and decreased at a greater or lesser rate afterwards.

As Schmidt[1] has made it plausible that the more quickly occurring disturbances are caused by wandering current vortices, we are led to the following supposition: A system of electric currents encompasses the Earth; at the occurrence of a magnetic disturbance, not only the strength of current is increased, but numerous current vortices are formed which wander over the Earth.

This system exhibits a strong analogy to the great cyclonic movement of the atmosphere around the poles, with its accompanying wandering depressions, as has been recently described by Hildebrand Hildebrandson.[2]

It being obvious to suppose that such a system of currents, with an axis not coinciding with the axis of rotation, but inclined at an angle of about 10°, must be influenced in some manner by the terrestrial rotation, the investigation was extended as follows:

Representing the hourly values of the horizontal intensity and declination on the first or second day following a day of disturbance by $h_1', h_2', h_3', \ldots h_{24}'$; $d_1', d_2', d_3', \ldots d_{24}'$, and on the second or third day or on a still later day by

$$h_1'', h_2'', h_3'', \ldots h_{24}''; \quad d_1'', d_2'', d_3'', \ldots d_{24}'',$$

[1] *Meteorol. Zeitschr.* 1899, p. 385.

[2] *Les bases de la meteorologie dynamique* No. 6, 1903.

Digitized by Google

then for a number of cases were computed,

$$(h_1'' - h_1'),\ (h_2'' - h_2') \text{ - - - - } (d_1'' - d_1') \text{ - - - - } (d_{24}'' - d_{24}'),$$

and the averages of these respective values,

$$H_1,\ H_2 \text{ - - - - - } H_{24},\ D_1,\ D_2 \text{ - - - - - } D_{24}.$$

Letting the averages of these quantities be (H) and (D) respectively, then by taking the differences

$$\begin{aligned} \triangle\ h_1 &= H_1 - (H), & \triangle\ d_1 &= D_1 - (D), \\ \triangle\ h_2 &= H_2 - (H), & \triangle\ d_2 &= D_2 - (D), \\ &\text{etc.} & &\text{etc.} \\ \triangle\ h_{24} &= H_{24} - (H), & \triangle\ d_{24} &= D_{24} - (D), \end{aligned}$$

a system of hourly values was found for the components of the vector, representing the daily inequality of the vector of disturbance.

Vector diagrams were drawn according to these values, computed for a certain number of stations, but though they pointed to a real influence of terrestrial rotation, they were mostly too irregular to allow any conclusions to be reached as to the nature of this influence.

In 1899, Dr. Lüdeling[1] constructed the vector diagrams of the diurnal variation for the international polar stations and for Pawlowsk. He gives in his paper the rectangular components (*NS* and *EW*) for the horizontal vector. He found that the direction in which the vector curve progresses—whether *clockwise*, as prescribed by the Schuster and von Bezold researches, or *anti-clockwise*—depends primarily upon whether all days (disturbed and undisturbed), or simply the magnetically calm days (Wild's "normal" days), are embraced in the discussion.

The vector curves of the diurnal disturbing forces, with the exception of the one for Kingua Fjord (and partially for Godthaab), progressed in the *anti-clockwise* direction. He suggests, in conclusion, that the disturbances, as well as the diurnal variation, may be ascribed to a system of forces rotating around the Earth once in twenty-four hours, and that we may possibly be dealing with a system of ascending and descending electric currents rotating about some pole, as *e. g.* the magnetic or the polar-light pole.

[1] See *T. M.*, IV, p. 245.

Digitized by Google

The present paper gives the results of the investigation of the daily field of disturbing force and its rotation referred to above.

The history of magnetic science has shown that wrong notions of magnetic phenomena, such as the secular and the diurnal variations, disturbances, etc., prevailed as long as these phenomena were being investigated at one or at a small number of stations, and that a true understanding was reached only after an inquiry into the phenomenon in question was made at widely distributed points.

Accordingly, our first task was to derive the daily horizontal and vertical components of disturbing force for a number of stations distributed as widely as possible over the globe. The available material is scant, the necessary dates for "quiet" days failing for many stations. We may expect, however, that the publication of the recent international observations will materially enlarge the data.

The material used is as follows:

The values of the horizontal component derived by Lüdeling have been used without change; for the vertical component the following quiet days have been taken into account:

	1883	
Cape Thordsen:	June	4, 5, 10, 12, 15.
	July	3, 4, 12, 20, 21, 22, 23, 28.
	August	4, 9, 10, 16, 17, 20.
Kingua Fjord:	June	4, 5, 6, 10, 11, 12, 15.
	July	3, 4, 12, 20, 21, 22, 23, 28.
Novaja Semlja:	June	4, 5, 15, 29.
	July	21, 22, 23, 28, 29.
	August	4, 9, 16, 17, 26, 31.
Bossekop:	June	5, 11, 15.
	July	21, 28, 29.
Point Barrow:	June	4, 5, 10, 11, 12, 15.
	July	3, 4, 20, 21, 22, 23, 28.
Jan Mayen, Sodankylä, Fort Rae:	June, July	Results taken directly from the respective publications.
Pawlowsk:	June	4, 5, 10, 11, 12, 15.
	July	3, 4, 12, 20, 21, 22, 23, 28.

The variations of the vertical intensity read at *Ssagastyr*, with the aid of a unifilar magnetometer provided with soft-iron induc-

Digitized by Google

tion bars, show such abnormal changes, that they evidently are less trustworthy, and, accordingly, they have not been used.

For *Greenwich* the hourly means of selected quiet days are published each year. Mean values for the components have been computed for the months of June and July of the ten years 1890–1899.

For *Tiflis* the days designated as normal or quiet for the three elements (*H*, *D*, and *Z*) at *Pawlowsk* have been used. The months of June and July for the years 1880–1884, 1886, 1887 have been selected for the horizontal component, and for the vertical component August was added.

For *Washington* the same quiet days as those for *Pawlowsk* for the months of June and July of the years 1889–1892, and also of 1894, have been chosen (taking into account the difference in time).

For *Batavia* the author had an opportunity to select the quiet days from the original magnetograms. The same dates have been adopted for *Zi-ka-wei*.

They are:

	June	July
1890	13, 14, 25	3, 16, 27, 28
1891	10, 11, 13	8, 9, 11, 13
1892	11, 12, 18	7, 8
1893	8, 17, 24	6, 8, 9, 31
1894	8, 27	27
1895	13, 14, 15, 20, 26	8, 10, 19, 25
1896	1, 2, 7, 11, 12, 13, 23, 24	.....
1897	9, 10	5, 13, 18

For *Cape Hoorn*[1] (June–July, 1883) the results for quiet days are given in the publication[2] for that station.

The results of the calculations for all these stations—viz., the components x_s, y_s, z_s, of daily inequality in disturbing force—have been collected in Table I.

[1] "*Hoorn*" is the true original spelling.

[2] *Mission Scientifique du Cap Horn*, 1882–1883, T. III.

Digitized by Google

TABLE I.

Diurnal Variation of Components of Disturbing Force.

[Unity = 0.00001 C. G. S.]

Local Mean Time	Kingua Fjord			Godthaab			Cape Thordsen			Jan Mayen			Fort Rae			Point Barrow			Novaja Semlja			Saagastyr		
	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s
1a	+23	−17	−13	− 3	− 8	. .	− 8	+13	−32	−34	+34	−40	+ 6	−21	−24	− 7	−23	− 6	−52	+11	−10	− 8	−16	. .
2	+22	−13	−24	+ 4	− 7	. .	− 9	+17	−32	−51	+40	−26	− 3	−23	−28	−10	− 9	. .	−58	+16	− 4	−33	−11	. .
3	+24	−11	−30	− 1	− 1	. .	− 5	+28	−24	−65	+56	−30	−22	−26	−59	0	− 9	+24	−61	+19	− 4	−49	+ 5	. .
4	+26	− 9	−17	− 6	+16	. .	−11	+44	−56	−43	+49	−26	−42	−28	−81	+16	− 8	. .	−37	+18	− 4	−54	+ 4	. .
5	+21	+ 7	−18	− 8	+26	. .	−17	+47	−49	−32	+49	−16	−42	−24	−68	− 5	− 8	+19	−24	+14	+ 3	−48	+16	. .
6	+28	+13	−27	−34	+51	. .	−13	+44	−30	−14	+37	−17	−52	−24	−67	−50	− 5	. .	−16	+ 9	+17	−35	+12	. .
7	+15	+23	−27	−32	+61	. .	+ 8	+26	−14	+ 2	+24	− 7	−80	−11	−71	−68	− 4	+37	− 7	+ 3	+ 9	−13	+12	. .
8	+16	+34	−19	−15	+43	. .	+32	+16	− 3	− 7	+24	− 5	−89	− 4	−28	−73	0	. .	+16	+ 1	+ 4	−21	+ 6	. .
9	+ 7	+40	−31	− 3	+36	. .	+36	+15	− 8	+ 8	+10	− 1	−66	+ 2	+14	−60	+ 8	+38	+24	+ 2	− 1	−17	+ 1	. .
10	+11	+53	− 5	+14	+31	. .	+59	+ 4	+ 5	+26	+ 8	− 1	−36	+10	+ 4	−19	+ 3	. .	+25	+ 3	− 5	−14	− 3	. .
11	+15	+61	+ 5	+37	+30	. .	+67	+17	+18	+47	− 2	+ 1	− 3	+13	+ 6	− 4	+ 6	+ 1	+20	+ 6	−11	− 4	+ 8	. .
Noon	+ 4	+61	+33	+81	+32	. .	+57	+ 1	+31	+51	− 6	+ 8	+12	+27	+ 1	+ 6	+ 4	. .	+10	− 1	−12	+ 5	+10	. .
1p	−28	+39	+57	+86	+11	. .	+34	0	+25	+72	−13	+17	+24	+37	− 5	+13	+12	− 8	+19	− 1	−15	+ 7	+ 7	. .
2	−56	+12	+36	+35	+ 5	. .	+12	− 9	+51	+60	−29	+31	+42	+40	−11	+10	+24	. .	+45	0	−20	+17	+ 9	. .
3	−56	− 4	+34	+10	− 3	. .	+ 4	−19	+38	+70	−47	+40	+58	+42	+ 1	+15	+21	−14	+40	− 5	−17	+30	+11	. .
4	−36	− 8	+21	−26	−21	. .	−14	−43	+59	+62	−46	+53	+56	+36	+43	+27	+17	. .	+31	−10	− 3	+41	+12	. .
5	−40	−22	+20	−30	−20	. .	−25	−36	+52	+ 7	−36	+56	+61	+28	+58	+33	+13	−38	+39	−10	− 1	+43	+10	. .
6	−29	−35	+16	−32	−36	. .	−47	−37	+39	+ 6	−44	+28	+55	+18	+65	+36	+11	. .	+53	−11	+ 6	+42	+10	. .
7	−12	−43	+ 6	−27	−51	. .	−35	−34	+25	−20	−42	+32	+38	− 2	+94	+42	+15	−42	+38	−13	+12	+56	+ 8	. .
8	− 5	−49	− 3	−18	−51	. .	−45	−33	+12	−42	−33	+15	+36	− 7	+75	+44	+ 5	. .	+20	−17	+13	+49	− 3	. .
9	+ 2	−45	−13	−13	−49	. .	−29	−24	+ 3	−50	−26	− 4	+28	−16	+51	+42	− 6	− 8	− 8	−18	+13	+26	−14	. .
10	+14	−35	− 1	−10	−42	. .	−25	−25	−20	−19	− 7	−23	+ 5	−26	+43	+26	−15	. .	−25	−15	+12	+19	−18	. .
11	+14	−28	−21	0	−32	. .	− 9	−12	−40	−21	+ 2	−36	+ 2	−29	+ 3	+ 1	−23	− 6	−49	− 6	+10	− 2	−23	. .
Midnight	+15	−20	−16	− 9	−12	. .	− 8	− 6	−54	−27	+11	−47	+ 0	−11	−13	− 6	−32	. .	−45	+ 9	− 2	−31	−34	. .

Digitized by Google

TABLE I—Continued.

Diurnal Variation of Components of Disturbing Force.

[Unity = 0.0000.1 C. G. S.]

Local Mean Time	Bossekop			Sodankylâ			Pawlowsk			Greenwich			Washington			Tiflis			Zi-wa-kei			Batavia			Cape Hoorn		
	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S	X_S	Y_S	Z_S
1a	−69	+25	+30	−59	+17	−41	− 3	+ 4	+15	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.4	+0.2	+0.8	−1.4	−0.5	−0.9	−0.4	−3.0	+0.4
2	−78	+24	+54	−52	+10	−37	+ 2	+ 3	+13	+0.7	+1.0	+8.2	+1.7	−2.2	+2.8	+4.7	+2.2	+1.6	+0.8	+1.1	+0.7	−0.6	+0.3	−1.0	−2.2	−2.7	+0.2
3	−92	+37	+65	-45	+11	−32	+ 1	− 1	+12	. .	. .	. .	. .	. .	. .	. .	. .	. .	+1.3	+1.9	+0.7	0.0	+0.7	−1.2	−0.5	−3.7	−0.2
4	−62	+27	+74	−32	+ 7	−23	− 2	+ 1	+ 9	+0.8	+2.0	+3.7	+1.2	−1.5	+4.4	+4.2	+1.2	+2.0	+1.5	+2.0	+0.8	+0.8	+1.2	−1.1	−0.4	−3.3	−0.5
5	−38	+16	+51	−22	+ 2	−14	− 2	− 4	+ 4	. .	. .	. .	. .	. .	. .	. .	. .	. .	+1.0	+2.9	+0.7	+1.7	+1.2	−1.1	+0.8	−2.1	−0.4
6	−19	+ 3	+40	−13	− 2	− 1	− 2	− 4	+ 4	+0.9	+4.6	+6.9	+2.2	+0.4	+4.7	+3.2	−1.3	+2.4	+0.4	+2.3	+0.5	+2.8	+1.5	−1.6	+2.4	−1.0	−1.1
7	0	+ 3	+12	− 2	0	− 9	− 3	− 2	+ 2	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.9	+1.2	+1.2	+2.6	+1.6	−0.3	+1.1	+1.4	+0.3
8	+ 6	0	− 1	+ 1	− 1	−10	− 3	− 2	+ 1	−0.5	+5.3	+5.0	−1.5	+0.5	+3.0	+1.4	−4.1	+1.0	+0.5	+0.4	+1.4	+3.0	+0.7	+1.0	+2.2	+2.9	−0.4
9	+ 9	0	− 7	+ 1	+ 1	+15	− 5	0	+ 1	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.1	−0.4	+1.2	+3.4	−0.3	+1.2	+3.5	+3.4	−0.9
10	+17	+ 2	− 9	+ 5	+ 5	+18	− 5	− 1	0	−2.2	+2.2	+2.8	−1.5	+1.9	+2.2	+0.4	−0.6	+0.2	+0.3	−1.1	+1.2	+3.2	−1.3	+1.9	+2.4	+3.2	−0.3
11	+15	+ 1	−11	+ 5	+ 5	+24	− 7	0	− 4	. .	. .	. .	. .	. .	. .	. .	. .	. .	−1.2	−1.2	+1.0	+3.0	−1.4	+3.4	+1.6	+3.1	−0.3
Noon	+36	− 1	−38	+16	+ 3	+27	− 3	− 3	−10	−0.3	−3.8	−1.3	−1.0	+2.9	−1.0	−3.2	+1.5	−1.8	−1.4	−0.6	0.0	+2.0	−0.8	+2.4	+0.6	+1.9	−1.6
1p	+55	− 4	−57	+21	− 1	+26	− 2	− 2	−10	. .	. .	. .	. .	. .	. .	. .	. .	. .	−1.4	−1.2	+0.5	+1.5	−0.8	+1.7	−0.1	+1.9	−0.3
2	+60	−12	−57	+36	− 7	+21	+ 1	− 3	−13	−1.7	−5.6	−0.3	0.0	+1.6	−2.2	−4.1	+1.4	−0.8	−1.0	−1.4	+1.1	0.0	−0.1	−0.2	+0.6	+1.8	−1.1
3	+69	−20	−77	+42	−10	+18	+ 5	− 2	−13	. .	. .	. .	. .	. .	. .	. .	. .	. .	−0.3	−1.7	0.0	−1.9	+0.8	−0.1	+1.3	+1.6	−0.4
4	+75	−23	−75	+48	−15	+26	+ 8	− 3	−14	0.0	−3.5	−8.1	+1.6	−1.0	−3.9	−4.0	−1.4	−1.2	−1.1	−1.6	0.0	−2.2	+0.7	0.0	+1.1	+1.1	−0.7
5	+89	−31	−76	+60	−14	+24	+13	− 1	−12	. .	. .	. .	. .	. .	. .	. .	. .	. .	−0.4	−0.5	−0.7	−2.7	+1.0	−0.4	+0.4	+0.9	−0.2
6	+73	−29	−63	+47	−16	+10	+ 7	0	− 8	+1.3	−1.4	−11.6	−0.6	+0.2	−4.4	−1.6	−0.3	−0.9	−0.3	−0.0	−0.8	−3.2	+1.0	−0.3	−1.7	+1.5	+0.1
7	+48	−32	−28	+40	−16	+14	+ 7	+ 2	− 5	. .	. .	. .	. .	. .	. .	. .	. .	. .	−1.5	−0.6	−1.1	−2.5	+0.6	−0.1	−2.2	+0.1	+1.1
8	+27	−25	−12	+16	−11	+ 4	+ 3	+ 1	− 1	+1.6	−0.8	−8.4	−2.8	+0.6	−4.9	−0.9	+1.9	−1.0	−0.4	−0.4	−1.5	−2.4	+0.1	−0.2	−2.5	0.0	+1.5
9	−12	− 8	+19	− 9	− 1	− 6	+ 2	+ 4	+ 3	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.4	−0.3	−1.3	−2.9	−0.6	0.0	−1.5	−0.5	+1.3
10	−43	− 1	+53	−19	+ 1	−14	− 2	+ 4	+ 5	+1.1	−0.4	+1.4	−0.2	+0.8	−1.6	−0.5	+2.6	−0.9	+0.9	−0.5	−1.6	−3.4	−0.6	−0.1	−2.7	−0.5	+1.3
11	−62	+13	+53	−37	−10	−19	− 4	+ 5	+ 9	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.5	−0.7	−1.4	−2.4	−1.2	−0.4	−2.9	−2.8	+0.6
Midnight	−80	+26	+48	−48	+13	−19	− 5	+ 3	+12	+0.9	+0.4	+4.4	+0.4	−2.8	+1.5	+0.1	+4.0	−0.6	−0.6	+0.1	+0.7	−1.8	−0.8	−0.8	−2.1	−3.7	+1.2

Digitized by Google

VECTOR DIAGRAMS OF THE HORIZONTAL COMPONENT OF THE DIURNAL DISTURBING FORCE.

The first plate[1] exhibits these vector diagrams for *Kingua Fjord*, *Godthaab*, *Jan Mayen*, *Sodankylä*, *Greenwich*, *Tiflis*, *Zi-ka-wei*, *Batavia*, and *Cape Hoorn*, drawn with the aid of "smoothed" components, and using different scales, in order to preserve the general shape as much as possible.

The characteristic features of these diagrams, taking them in the order of succession determined by these characteristics, briefly described are:

Kingua Fjord. The vector moves clockwise throughout the day, with only small change in magnitude.

Godthaab. From 3^ha till 3^hp the vector moves anti-clockwise, and clockwise during the rest of the day; it vanishes as the direction of rotation changes. The vector diagram approaches the form of the figure 8.

Cape Thordsen. The diagram for this station may be considered to be derived from that of the preceding station of *Godthaab* by turning around the afternoon part in which the vector rotates clockwise. At 1^ha and 4^hp the vector nearly vanishes, but the rotation is anti-clockwise for the whole day.

Jan Mayen, *Fort Rae*, *Point Barrow*, *Novaja Semlja*, and *Ssagastyr.* The vector moves more or less regularly in an anti-clockwise direction; at the hours after midnight and noon it is larger than at about midnight and noon.

This latter feature is strongly developed at *Bossekop;* hence the diagram for this station exhibits a very oblongated form.

At *Sodankylä* the lower parts of the diagram seem to have crossed each other, forming a small loop. The curve progresses partly in the clockwise direction and partly in the opposite direction.

Pawlowsk. The vector moves anti-clockwise in the morning and clockwise in the afternoon; the diagram does not show the figure-8 form, but is partially curved inwardly, and approaches the simpler form of the *Greenwich* diagram, where the vector rotates regularly for almost the whole day in a clockwise direction.

Tiflis. The direction is anti-clockwise for the first part of the day and clockwise during the second part, the diagram showing the

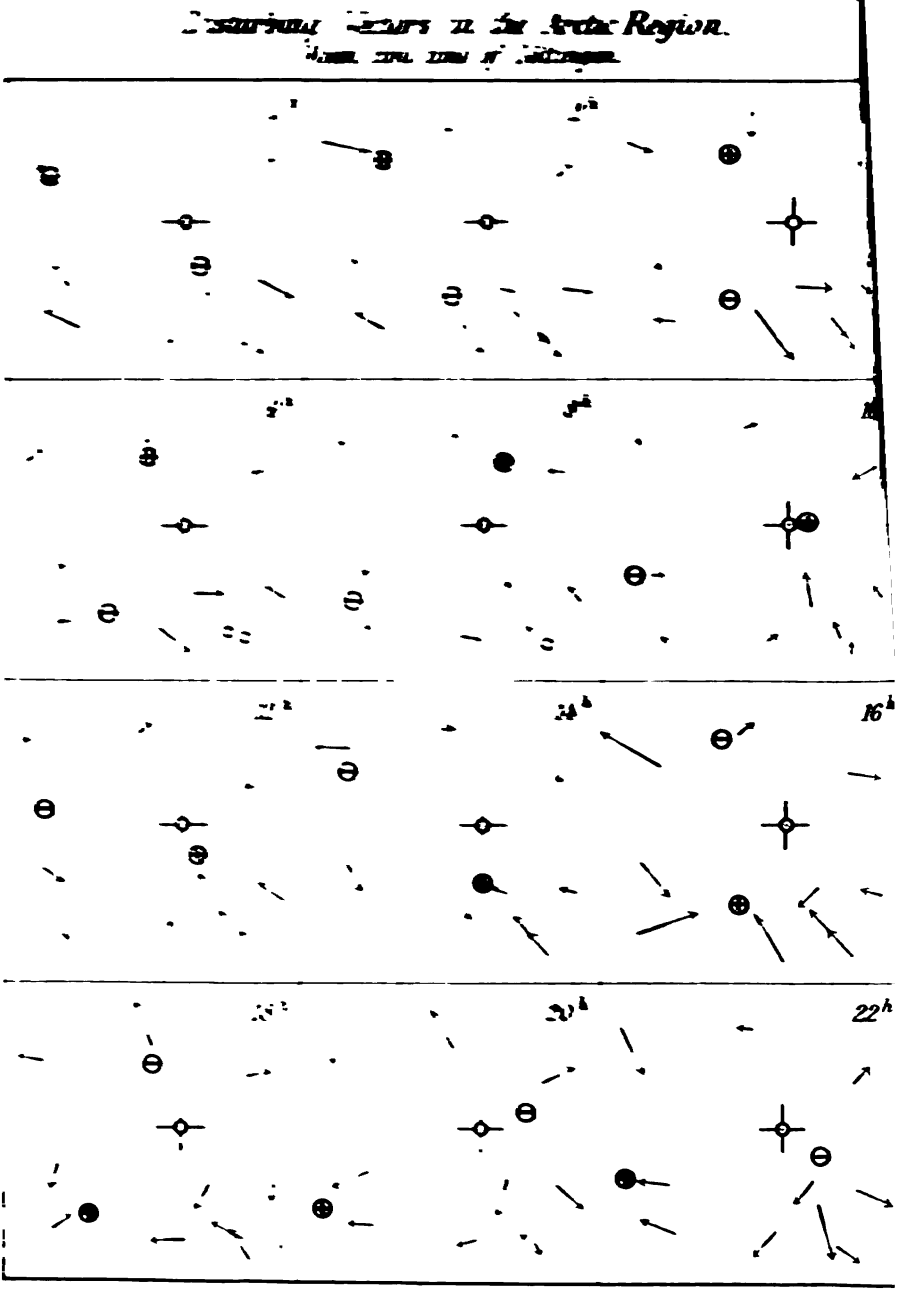
[1] Both plates were printed at Batavia, and the requisite number furnished to the Journal by the author.—ED.

Digitized by Google

PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS

Digitized by Google

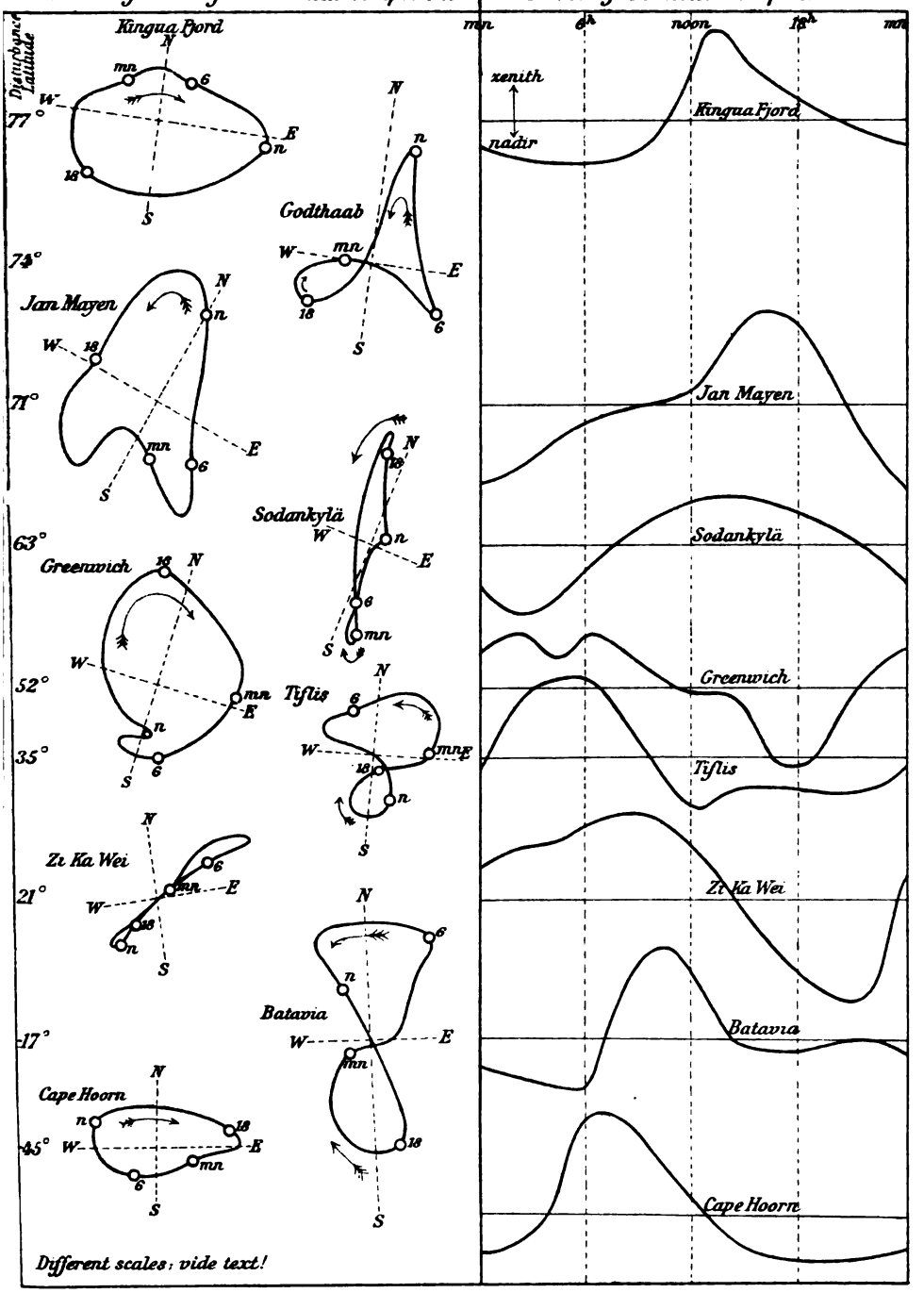


Digitized by Google

Daily Variation of Disturbing Force.

Vectordiagrams of horizontal component

Curves of vertical component.



Digitized by Google

figure-8 form and the vector vanishing before midnight and before noon.

Also for *Washington* such a diagram has been found, but of a more complicated character, evidently an effect of insufficient material. Notwithstanding, the vector rotates anti-clockwise regularly from 4^h a till 4^h p.

Zi-ka-wei. The diagram may be compared with that of *Sodankylä*. For both stations the diagram is so oblongated that the vector may be said to keep a constant direction, changing only in amount. The direction is nearly N/S for *Sodankylä*, but more E/W for *Zi-ka-wei*.

Batavia. The diagram is almost the same as that for *Tiflis*, only that the vector vanishes in this case shortly *after* midnight and noon.

The diagram of our most southerly station, *Cape Hoorn*, shows nearly the same features as that for *Greenwich*.

These stations for which diagrams have been described are recapitulated here, together with their geographical and their auroral latitudes. By the latter are meant the complements of the spherical distance from the pole of the aurora borealis.

Station	Latitude Geogr.	Auroral.	Station	Latitude Geogr.	Auroral.
Kingua Fjord	67°	77°	Sodankylä	68°	63°
Godthaab	64	74	Pawlowsk	60	54
Cape Thordsen	78	73	Greenwich	51	52
Jan Mayen	71	71	Washington	39	51
Fort Rae	63	70	Tiflis	42	35
Point Barrow	71	70	Zi-ka-wei	31	21
Novaja Semlja	72	63	Batavia	— 6	—17
Ssagastyr	73	62	Cape Hoorn	—55	—45
Bossekop	70	66			

The regularity in decrease shown by the auroral latitude, as contrasted with the irregular succession of geographical latitudes, is obvious; this is not wholly unexpected, as the vector of disturbance is directed perpendicularly to the isochasms, which have a course resembling that of true parallels around the auroral axis. And as these isochasms show certain deviations from the true auroral parallels, the small irregularity in the succession above mentioned shown by *Bossekop* and *Sodankylä* (respectively 66° and 63°) may be safely disregarded.

Digitized by Google

The deviations of the isochasms from the auroral parallels make it impossible to determine accurately the place of the aurora-pole. From his observations of aurora, Nordensköld[1] adopted 81° N and 80 W, this place corresponding very nearly with the point where the meridians of disturbing vectors, mentioned above, converge. (Nachstörungsmeridiane, Cf. *Meterol. Zeitschr.* 1895 l. c.)

It is by reason of this uncertainty in the place of aurora-pole, that for our purpose another pole has been used, situated close to it, viz., in 79° N and 78° W, which may be called the pole of disturbance, and which will be considered further on.

VERTICAL COMPONENT OF THE DIURNAL DISTURBING FORCE.

(Directed positive towards zenith.)

In general this component exhibits a single diurnal variation with amplitude of the same order as for the horizontal component. For the stations: *Kingua Fjord*, *Cape Thordsen*, *Jan Mayen*, *Fort Rae* and *Sodankylä* the character of the inequality is chiefly the same with a minimum in the morning and a maximum in the afternoon. For *Novaja Semlja* we find two maxima and two minima and a small amplitude; the oscillation seems to be of a transitional form between the former type and that for *Pawlowsk*, *Greenwich*, *Tiflis* and *Zi-ka-wei*, where we find just the contrary type with a maximum in the morning and a minimum in the afternoon.

In two cases this regular system is broken, viz. for *Point Barrow* and *Bossekop* where the diurnal inequality is just the contrary of what is to be expected. This is especially remarkable for *Bossekop*, as the corresponding horizontal hourly vectors at the neighboring station, *Sodankylä*, have nearly the same directions as those at *Bossekop*.

The rest of the stations falling in so well with the general system of the diurnal inequality of the vertical component, I think it best to consider these two cases as local deviations caused perhaps by abnormal phenomena of induction discussed later.

The inequality at *Batavia* shows a maximum at about noon and a minimum in the morning, and for *Cape Hoorn* we find the same type again as for *Pawlowsk*, *Greenwich*, *Tiflis*, and *Zi-ka-wei*.

A tabulation of the direction of the horizontal vector and of the maxima and minima of the vertical component is as follows:

[1] *Ann. de Chimie et de Physique*, 1884.

Digitized by Google

Latitude of Disturbance	Station	Horizontal vector moves	Vertical component has a maximum	Vertical component has a minimum
77°	Kingua Fjord	clockwise	afternoon	morning.
74	Godthaab	clockwise and anticlockwise	?	
73	Cape Thordsen	anti-clockwise	afternoon	morning.
71	Jan Mayen	"	"	"
70	Fort Rae	"	"	"
70	Point Barrow	"	morning!	afternoon!
63	Novaja Semlja	"	tends to disappear.	
62	Ssagastyr	"	?	
66	Bossekop	"	morning!	afternoon!
63	Sodankylä	anti-clockwise and clockwise	afternoon	morning.
54	Pawlowsk	clockwise and anti-clockwise	morning	afternoon.
52	Greenwich	clockwise.	"	"
51	Washington	anti-clockwise and clockwise	"	"
35	Tiflis	" " "	"	"
21	Zi-ka-wei	constant direction	"	"
—27	Batavia	anti-clockwise and clockwise	noon	morning.
—45	Cape Hoorn	clockwise	morning	afternoon.

Having thus investigated and correlated the character of the vector diagrams and the inequality of the horizontal and the vertical components at various stations, the natural step next was to study the synchronous system of vectors for different moments during one rotation of the Earth.

For this purpose we may restrict ourselves to the Arctic stations which lie relatively close to each other; the original observations at these stations having been taken at the Göttingen hours they are consequently truly synchronous.

To obtain a survey of these synchronous systems, 12 maps of the north polar cap have been constructed in stereographic projection. They are reproduced on the first plate (left hand side), inserted between pages 160 and 161.

The star with four rays represents the north pole, and the arrows give the direction and length of the horizontal vectors. The values of the components x_s and y_s, as given by Lüdeling in his quoted paper, have been used.

The names of the stations, viz. Kingua Fjord, Godthaab, Cape Thordsen, Jan Mayen, Bossekop, Sodankylä, Novaja Semlja, Ssagastyr, Point Barrow, and Fort Rae have not been inscribed in order not to confuse the aspect of the system of synchronous vectors corresponding to the 12 moments: 0^h, 2^h, 4^h - - - - 22^h mean time of Göttingen. An inspection of these 12 maps shows

Digitized by Google

that one portion of the vectors points towards one focus, and that the other portion radiates from another focus.

This is especially striking for the vectors at the neighboring stations, Cape Thordsen, Jan Mayen, Bossekop, Sodankylä and Novaja Semlja for the hours, 0^h, 12^h, 14^h, 22^h.

On each map the places of these foci have been indicated by small circles in which a + or — sign has been inscribed, the + sign for the focus towards which the vectors point, and the — sign for the one from which they radiate. As there is chance for personal bias in the choice of these places, the maps are reproduced subject to the reader's criticism.

For a determination of the foci a rectangular system of coordinates, with the origin in the north pole, has been used. For the positive X axis and positive Y axis, respectively, the meridians of 180° and 90° W from Greenwich have been taken. For unit of length 2 tan 0°.5 has been chosen, because the maps have been drawn in stereographic projection from the south pole; accordingly $\sqrt{(x^2+y^2)} = \tan p$, p being the polar distance expressed in degrees. As p is small for most Arctic stations, we may take p for tan p, and consequently consider one degree as the unit of length.

Göttingen mean time	Positive focus x	Positive focus y	Negative focus x	Negative focus y
Midnight	7.4	—22.2	— 8.2	1.6
2^h	9.6	—17.0	—13.2	— 5.4
4	11.2	—11.0	—13.2	— 8.8
6	11.2	— 6.2	—16.0	—11.6
8	8.8	2.2	—12.6	—21.2
10	0.0	2.2	— 8.8	—28.0
Noon	— 4.4	2.2	2.2	—23.6
14	— 8.8	— 0.6	8 8	—23.6
16	—11.8	— 6.6	13.8	—10.4
18	—14.0	—15.4	9.4	— 6.0
20	—13.2	—26.2	2.8	8.2
22	— 8.8	—30.2	— 6.2	6.2
Mean	— 1.1	—10.7	— 3.4	—10.2

The 12 maps show that both foci change their positions from hour to hour; combining the 12 positions for each focus in a special map, it is obvious that the orbit for each approaches a common circle, in which the foci lie diametrically opposite to each other.

Digitized by Google

To investigate this, the harmonic formulæ representing the four series, respectively for x_+, x_-, y_+, and y_-, have been computed.

$$+\text{ focus}\begin{cases} x_+ = -\ 1.1 + 13.5 \sin (t + 15^\circ) + 2.1 \sin 2\ (t + 19^\circ) \\ y_+ = -\ 10.7 + 14.3 \sin (t + 14^\circ - 90^\circ) + 2.4 \sin 2(t - 2^\circ) \end{cases}$$

$$-\text{ focus}\begin{cases} x_- = -\ 3.3 + 13.6 \sin (t + 24^\circ + 180^\circ) + 3.2 \sin 2(t - 15^\circ) \\ y_- = -\ 10.2 + 15.7 \sin (t + 24^\circ + 90) + 3.0 \sin 2(t - 50^\circ) \end{cases}$$

The mean values of x_+, y_+, x_-, and y_-, viz., the constant terms of these formulæ, are nearly the same for both foci:

-1.1 and -3.4 ; -10.7 and -10.2.

Accordingly both paths have nearly the same central point.

The terms of the second order are small compared with those of the first order; neglecting them and considering those of the first order only, we see that the amplitudes are nearly of the same magnitude, and that the phase angles, viz. for x - - - - 15° and $24^\circ + 180^\circ$ and for y - - - - $14^\circ - 90^\circ$ and $24^\circ + 90^\circ$, differ nearly 180°, thus pointing to a circular path, in which the two foci have a diametrical position.

If we adopt the path as being the same for both foci, having its center at $x_0 = \frac{1}{2}(-1.1 - 3.4) = -2.3$, and $y_0 = \frac{1}{2}(-10.7 - 10.2) = -10.5$ and the foci occupying diametrical positions, the values: $(x - x_0)_n^h$, $(y - y_0)_{(n+6)^h}$, $-(x - x_0)_{(n+18)^h}$, $-(y - y_0)_{(n+18)^h}$ must represent the same quantity, and we may derive a new set of 12 values by taking the mean of each group of four. The harmonic formula computed for this set is:

$X_+ = -2.3 + 14.5 \sin (t + 22^\circ) + 1.3 \sin 2(t + 28^\circ)$.

The term of the second order has been still more diminished; furthermore the phase angles, viz. the angles $2 \times 19^\circ$, $-2 \times 2^\circ$, $-2 \times 15^\circ$ and $-2 \times 50^\circ$, show no regularity at all; accordingly we are justified in neglecting the term of the second order and in putting forth the conclusion:

The positive and negative foci of the Arctic vectors of the diurnal variation of the disturbing force move daily in a clockwise direction, with constant velocity and diametrically opposite to each other in a circular path of 14°.5 radius, having its center in 79° N and 78° W.

Combining the two results, viz.:

1°. The Arctic vectors point to a couple of foci, which rotate daily clockwise around the pole of disturbance;

Digitized by Google

2°. The character of the vector diagrams is chiefly dependent on the distance from this same pole; it is quite natural to draw the conclusion:

The daily inequality of disturbing force is caused by a constant field of force rotating from E to W around the axis of disturbance.

This constancy should be understood in this way, that the rotating field suffers only minor alterations, when the disturbance influence to which the Earth is exposed does not vary.

For the pole of aurora borealis, I accepted 80°.5 N and 80° W and according to Schmidt, the magnetic axis for 1885 cuts the Earth's surface in 78°.5 N and 68°.5 W, hence in the vicinity of the place where the disturbance axis found above, cuts the surface.

THE DIURNAL FIELD OF DISTURBANCE.

In order to obtain a representation of this field it is best to distribute the successive hourly values of the components of a certain number of stations, situated on different parallels along the parallels and to draw the lines of equal vertical component together with the horizontal vectors. Parallels must be taken with regard to the axis of disturbance.

It is obvious that the features of the system of lines of equal vertical component will suffer strongly from local deviations from the general type of inequality pertaining to the region in which the station is situated. For instance, if to the vertical components of the stations: Kingua Fjord, Cape Thordsen, Jan Mayen, and Sodankylä, which exhibit one and the same type of inequality, are added those for Barrow and Bossekop, of the contrary type, then the lines of equal vertical component will acquire a distorted aspect. The aim being a knowledge of the causes of the phenomenon, a representation of the field exhibiting only the chief characteristic features free from local deviations is required. The investigation of the local deviations is of later care; for the present the knowledge that important deviations exist may be considered to be sufficient.

Of course we may suppose the field to change during one rotation in such a degree, that it would be necessary to derive a representation of it for each hour, but the agreement between most of the vector diagrams (the two stations: Point Barrow and Bossekop included) points to the contrary conclusion.

Just as Schuster,[1] in his representation of the diurnal variation field, selected a small number of stations situated on parallels

[1] *Philosophical Transactions* 180, p. 467.

Digitized by Google

already known as critical for the phenomenon, so in our case those stations have been selected, which have well developed diagrams, characteristic for each of the different types.

Accordingly Kingua Fjord, Jan Mayen, Sodankylä, Greenwich, Tiflis, Zi-ka-wei, Batavia, and Cape Hoorn have been chosen; (Godthaab has been omitted, the vertical component for that station not being available).

First, the hourly values of the components for these stations have been smoothed graphically, because it was clear that the irregularities in the series had been caused chiefly by want of material. From the smoothed curves representing the values of x_s, y_s, and z_s for the selected stations, the values for the full hours of Göttingen mean time have been read. They are given in Table II. Now these values have been computed in most cases for the same pair of months, viz., June—July, but not for the same years. As it is probable that the diurnal inequality of disturbing force increases and decreases together with the force itself in the eleven year period, the figures are not comparable directly. A factor reducing them to the same year may be found as follows:

In the "Observations made at the Royal Magnetical and Meteorological Observatory at Batavia," 1898 part II, table 69, we find the mean horizontal disturbance (s_h) per day and from these values we may derive the formula

$$s_h = 22 + 1.00\,R\ ,$$

R being Wolf's Sun-spot number.

With this formula we find for the reducing factors: Greenwich, 1.27; Tiflis, 1.27; Batavia, 1.17.

As these factors differ not much from unity and are moreover approximations, and also as the components of these stations themselves are small in comparison with Arctic values, no use has been made of these factors.

The construction of the field has been performed in the following manner.

A map of the Earth has been constructed after Mercator's projection, not with the axis of rotation as chief axis, but with regard to the axis of disturbance. The great circle passing through the pole of disturbance and the place, where the Sun stands in the zenith at Greenwich mean noon of July 1st, has been chosen as middle or zero meridian.

The place occupied in this projection by the other stations selected has been computed to be:

Digitized by Google

TABLE II.

Diurnal Variation of Components of Disturbing Force.
Smoothed Values for Eight Selected Stations.

[Unity = 0.00001 C. G. S.]

Mean Goettingen Time	Kingua Fjord			Jan Mayen			Sodankylä			Greenwich			Tiflis			Zi ka wei			Batavia			Cape Horn		
	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s
1a	− 5	−49	+ 2	−27	+ 16	−47	−52	+ 13	38	+ 0.8	+ 4.8	+ 5.0	+ 4.5	+ 1.6	+ 1.9	0.0	0.0	+ 1.2	+ 3.2	+ 0.9	+ 0.4	1.4	1.2	+ 1.4
2	+ 3	−45	− 3	−35	+ 30	−40	44	+ 10	− 37	+ 1.2	+ 4.7	+ 7.4	+ 4.1	+ 0.7	+ 2.1	− 0.4	0.5	+ 1.1	+ 3.4	0.0	+ 1.5	1.4	1.9	+ 1.4
3	+ 9	−36	− 8	41	+ 34	−34	33	+ 6	−31	+ 1.7	+ 5.0	+ 7.4	+ 3.6	0.4	+ 2.3	0.8	0.8	+ 1.1	+ 3.3	+ 1.1	+ 2.3	1.2	2.4	+ 1.3
4	+14	−28	−12	− 65	+ 52	−28	22	+ 2	23	+ 1.2	+ 5.4	+ 5.0	+ 2.9	+ 1.9	+ 2.1	+ 1.1	− 1.0	+ 0.9	+ 2.9	+ 1.8	+ 2.8	0.8	3.1	+ 1.0
5	+18	−21	−16	− 46	+ 53	−23	− 12	0	− 13	−0.6	+ 5.2	+ 3.6	+ 2.0	+ 3.7	+ 1.6	+ 1.2	+ 1.1	+ 0.7	+ 2.3	+ 1.1	+ 2.6	+ 0.1	3.8	+ 0.8
6	+21	−17	−19	−30	+ 46	18	2	− 1	− 3	− 3.3	+ 3.6	+ 5.6	+ 1.2	+ 3.8	+ 1.1	− 1.2	+ 1.2	+ 0.4	+ 1.4	+ 0.7	+ 1.8	+ 0.7	3.7	+ 0.5
7	+23	−13	−21	− 19	+ 37	−13	0	0	+ 5	−4.6	+ 1.7	+ 6.9	+ 0.7	+ 1.5	+ 0.4	− 1.1	+ 1.3	+ 0.1	+ 0.3	+ 0.2	+ 0.4	+ 1.3	3.7	+ 0.3
8	+24	− 9	−23	− 8	+ 29	− 9	+ 1	+ 2	+ 12	−4.8	0.0	+ 5.9	+ 0.2	+ 0.1	+ 0.3	+ 1.0	+ 1.2	+ 0.2	+ 1.2	+ 0.3	+ 0.0	+ 1.7	− 3.3	+ 0.2
9	+24	− 3	−24	+ 1	+ 21	− 4	+ 4	+ 5	+ 17	− 4.9	+ 0.9	+ 4.7	+ 1.6	+ 1.0	+ 1.1	+ 0.9	+ 1.0	+ 0.5	+ 2.2	+ 0.7	+ 0.2	+ 2.0	+ 2.5	+ 0.4
10	+23	+ 5	− 24	+ 11	+ 13	− 2	+ 8	+ 5	+ 21	+ 5.0	+ 1.3	+ 3.6	+ 3.5	+ 1.7	+ 1.5	+ 0.8	+ 0.8	+ 0.8	+ 2.6	+ 0.9	+ 0.2	+ 2.2	+ 1.2	+ 0.5
11	+22	+ 14	−24	+ 35	+ 6	− 1	+ 15	+ 3	+ 24	−4.8	−1.3	+ 2.0	+ 4.0	+ 1.8	+ 1.3	+ 0.7	+ 0.6	+ 1.1	+ 2.9	+ 1.0	+ 0.2	+ 1.9	+ 0.6	+ 0.5
Noon	+20	+ 23	−23	+ 43	− 1	+ 2	+ 23	− 1	+ 25	−4.3	+ 0.5	+ 0.1	+ 4.2	+ 1.0	+ 1.1	+ 0.6	+ 0.5	+ 1.3	+ 3.0	+ 0.8	+ 0.2	+ 1.4	+ 2.4	+ 0.5
1p	+18	+ 32	−21	+ 56	− 8	+ 8	+ 32	− 6	+ 26	+ 3.5	+ 0.3	− 1.3	+ 4.2	− 0.5	+ 1.0	+ 0.5	+ 0.4	+ 1.4	+ 3.1	+ 0.2	+ 0.1	+ 0.8	+ 4.0	+ 0.6
2	+15	+ 42	−16	+ 65	−17	+ 18	+ 41	− 10	+ 26	+ 2.5	+ 0.7	− 0.4	+ 3.7	+ 1.5	+ 1.0	+ 0.4	+ 0.4	+ 1.5	+ 3.1	+ 0.4	+ 0.1	+ 0.2	+ 4.6	+ 0.6
3	+11	+ 53	− 7	+ 70	−28	+ 30	+ 51	−14	+ 25	+ 1.3	+ 3.5	−1.0	+ 2.2	− 1.0	+ 1.0	+ 0.2	+ 0.4	+ 1.4	+ 3.0	+ 0.7	− 0.1	+ 0.1	+ 4.1	+ 0.6
4	+ 7	+ 61	+ 7	+ 68	− 40	+ 41	+ 60	+ 15	+ 23	+ 0.6	− 4.4	−6.0	+ 1.4	+ 0.1	+ 1.0	+ 0.0	+ 0.1	+ 0.8	+ 2.4	+ 1.0	+ 0.3	+ 0.3	+ 3.3	+ 0.6
5	− 3	+ 61	+ 33	+ 58	− 44	+ 53	+ 50	+ 16	+ 19	+ 2.7	− 4.9	− 9.3	+ 1.1	+ 1.1	− 1.0	+ 0.2	+ 0.3	+ 0.4	+ 2.0	+ 0.9	+ 0.6	+ 0.5	+ 2.5	+ 0.6
6	−28	+ 39	+ 57	+ 29	− 44	+ 56	+ 35	− 15	+ 15	+ 6.3	+ 4.0	−11.0	− 0.8	+ 1.9	+ 1.0	+ 0.7	+ 0.9	+ 0.8	+ 1.4	+ 0.8	+ 0.9	+ 0.6	+ 2.1	+ 0.6
7	−56	+ 17	+ 43	− 1	− 43	+ 42	+ 15	− 11	+ 9	+ 7.5	− 2.0	− 11.5	− 0.6	+ 2.6	− 0.9	+ 1.2	+ 1.5	+ 0.7	+ 0.8	+ 0.0	+ 1.0	+ 0.8	+ 1.8	+ 0.5
8	−56	0	+ 33	−22	− 40	+ 26	− 8	− 4	+ 3	+ 7.0	+ 0.2	− 10.5	+ 0.4	+ 3.1	− 0.9	+ 1.4	+ 2.2	+ 0.7	+ 0.1	+ 0.5	+ 1.1	+ 1.1	+ 1.6	+ 0.5
9	−46	− 12	+ 24	− 40	− 33	+ 11	−22	+ 3	− 4	+ 5.9	+ 2.2	− 6.7	− 0.2	+ 3.7	+ 0.7	+ 1.2	+ 2.7	+ 0.7	+ 0.7	+ 0.9	+ 1.2	+ 1.3	+ 1.2	+ 0.4
10	−35	− 25	+ 18	− 50	− 23	− 6	−37	+ 9	− 13	+ 4.7	+ 4.0	0.0	+ 0.7	+ 3.8	− 0.3	+ 1.0	+ 2.5	+ 0.8	+ 1.5	+ 1.2	+ 1.3	+ 1.4	+ 0.7	+ 0.2
11	−23	− 35	+ 12	− 23	− 11	− 22	− 49	+ 14	− 12	+ 3.3	+ 5.2	+ 2.0	+ 4.1	+ 3.2	+ 1.1	+ 0.7	+ 1.5	+ 1.0	+ 2.2	+ 1.4	+ 1.3	− 1.5	+ 0.1	+ 0.2
12	−12	− 43	+ 7	− 21	+ 3	− 36	−59	+ 15	− 31	+ 1.9	+ 5.4	+ 3.3	+ 4.7	+ 2.3	+ 1.6	+ 0.4	+ 0.6	+ 1.2	+ 2.8	+ 1.6	0.6	− 1.5	− 0.6	+ 0.9

Digitized by Google

TABLE III.

Diurnal Variation of the Smoothed Values of the Horizontal Component of Magnetic Force Directed Along the Meridians and Parallels of Disturbance for Eight Selected Stations.

[Unity = 0.00001 C. G. S.]

Mean Goettingen Time	Kingua Fjord		Jan Mayen		Sodankylä		Greenwich		Tiflis		Zi-ka-wei		Batavia		Cape Hoorn	
	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s
1a	+ 5	−49	−31	− 3	−52	−10	−0.8	+4.8	+4.1	+2.5	0.0	0.0	+3.2	+0.9	−1.4	−1.2
2	+12	−43	−46	+ 3	−44	− 9	−0.5	+4.8	+3.9	+1.5	−0.5	−0.5	+3.4	0.0	−1.4	−1.9
3	+16	−33	−53	+ 2	−33	− 9	−0.1	+5.3	+3.6	+0.3	−0.9	−0.7	+3.3	−1.1	−1.2	−2.4
4	+20	−24	−83	+ 3	−21	− 7	−0.7	+5.5	+3.2	−1.3	−1.2	−0.9	+ 2.9	−1.5	+0.8	−3.1
5	+22	−17	−68	+15	−11	− 5	−2.3	+4.7	+2.7	−3.2	−1.3	−1.0	+2.3	−1.1	+0.1	−3.5
6	+24	−13	−52	+19	− 2	− 2	−3.3	+2.3	+ 2.0	−3.5	−1.3	−1.1	+1.4	−0.7	+0.7	−3.7
7	+26	− 8	−37	+19	0	0	−4.9	+0.1	+1.0	−1.4	−1.2	−1.2	+0.3	−0.2	+1.3	−3.7
8	+26	− 4	−23	+19	0	+ 2	−4.5	−1.6	+0.2	−0.1	−1.1	−1.1	−1.2	+0.3	+1.7	−3.3
9	+25	+ 2	−12	+18	+ 2	+ 7	−4.3	−2.4	−1.8	+0.7	−1.0	−0.9	−2.2	+0.7	+2.0	−2.5
10	+22	+10	+ 1	+17	+ 5	+ 8	−4.3	−2.9	−3.7	+1.0	−0.9	−0.7	−2.6	+0.9	+2.2	−1.2
11	+21	+18	+24	+26	+13	+ 9	−4.1	−2.8	−4.3	+1.0	−0.8	−0.5	−2.9	+1.0	+1.9	+0.6
Noon	+15	+27	+35	+26	+21	+ 9	−3.8	−1.9	−4.3	+0.2	−0.7	−0.4	−3.0	+0.8	+1.4	+2.4
1p	+12	+35	+50	+28	+32	+ 8	−3.4	−0.9	−4.0	−1.3	−0.5	−0.3	−3.1	+0.2	+0.8	+4.0
2	+ 7	+44	+62	+25	+41	+ 8	−2.2	−1.5	−3.3	−2.2	−0.4	−0.4	−3.1	−0.4	+0.2	+4.6
3	+ 1	+54	+73	+20	+52	+ 8	0.0	−3.7	−2.0	−1.4	−0.2	−0 4	−3.0	−0.7	−0.1	+4.1
4	− 5	+61	+78	+ 9	+61	+11	+2.1	−4.0	−1.5	−0'2	0.0	−0.1	−2.4	−1.0	−0.3	+3.3
5	−15	+59	+72	0	+52	+ 6	+4.1	−3.7	−1.3	+0.9	+0.2	+0.3	−2.0	−0.9	−0.5	+2.5
6	−35	+33	+50	−16	+38	+ 1	+7.2	−1.7	−1.2	+1.7	+0.8	+0.8	−1.4	−0.5	−0.6	+2.1
7	−58	+ 6	+25	−35	+19	− 4	+7.8	+0.6	−1.1	+2.4	+1.4	+1.4	−0.8	0.0	−0.8	+1.8
8	−55	−11	+ 6	−45	− 5	− 7	+6.5	+2.5	−1.0	+2.9	+1.6	+2.1	−0.1	+0.5	−1.1	+1.6
9	−47	−21	−12	−50	−21	− 6	+4.8	+4.1	−0.9	+3.6	+1.5	+2.6	+0.7	+0.9	−1.3	+1.2
10	−39	−32	−26	−47	−38	− 8	+3.1	+5.4	−0.1	+3.8	+1.3	+2.4	+1.5	+1.2	−1.4	+0.7
11	−30	−39	−11	−23	−51	− 8	+1.4	+6.0	+3.4	+5.9	+0.9	+1.4	+2.2	+1.4	−1.5	+0.1
12	−20	−44	−19	−11	−60	−11	0.0	+5.7	+4.1	+3.3	+0.5	+0.6	+2.8	+1.6	−1.5	−0.6

Digitized by Google

Station	Disturbance Latitude	Disturbance Longitude
Kingua Fjord	78° N	64° W
Jan Mayen	71 N	21 E
Sodankylä	62 N	43 E
Greenwich	52 N	6 E
Tiflis	35 N	46 E
Zi-ka-wei	20 N	124 E
Batavia	18 S	101 E
Cape Hoorn	45 S	78 W

The components x'_s and y'_s, computed for this new system of co-ordinates from the smoothed values of x_s and y_s, are tabulated in Table III. The deviation of the new north, the north of disturbance, from the geographical north amounts at

Kingua Fjord	9° W	Tiflis	11½ W
Jan Mayen	35 W	Zi-ka-wei	6 E
Sodankylä	24 W	Batavia	1 E
Greenwich	18 W	Cape Hoorn	2 W

The vector diagrams reproduced in the first plate are constructed by means of these components x'_s and y'_s.

For reference the geographical N, E, S, and W directions have been added.

In the map (second plate, left hand side) the value of the vertical component z_s as well as the horizontal vector (x'_s, y'_s) at 12^h m. t. of Greenwich $= 12^h 40^m$ m.t. of Göttingen has been inscribed at the place of each station and from that point the successive hourly values along the parallel of the station at distances of 15° from W to E. Further the lines of equal vertical intensity have been drawn and thus the field of force has been constructed.

The arrows indicate merely the direction of the horizontal vector, their length not representing the magnitude which varies too greatly for the Arctic and tropical stations to make this practical.

In the case of the vector nearly vanishing, the arrow has been replaced by a small circle, the direction being very doubtful in this instance.

The map makes it evident, that the lines of equal vertical intensity inclose various foci, of which two may be said to be double. The eastern Arctic one, which shows two maxima over 50 γ (γ=0.00001 *C. G. S.*) owes this feature perhaps to the fact that for these regions the field depends on the values of two stations, Kingua Fjord and Jan Mayen, differing much in longitude. It

Digitized by Google

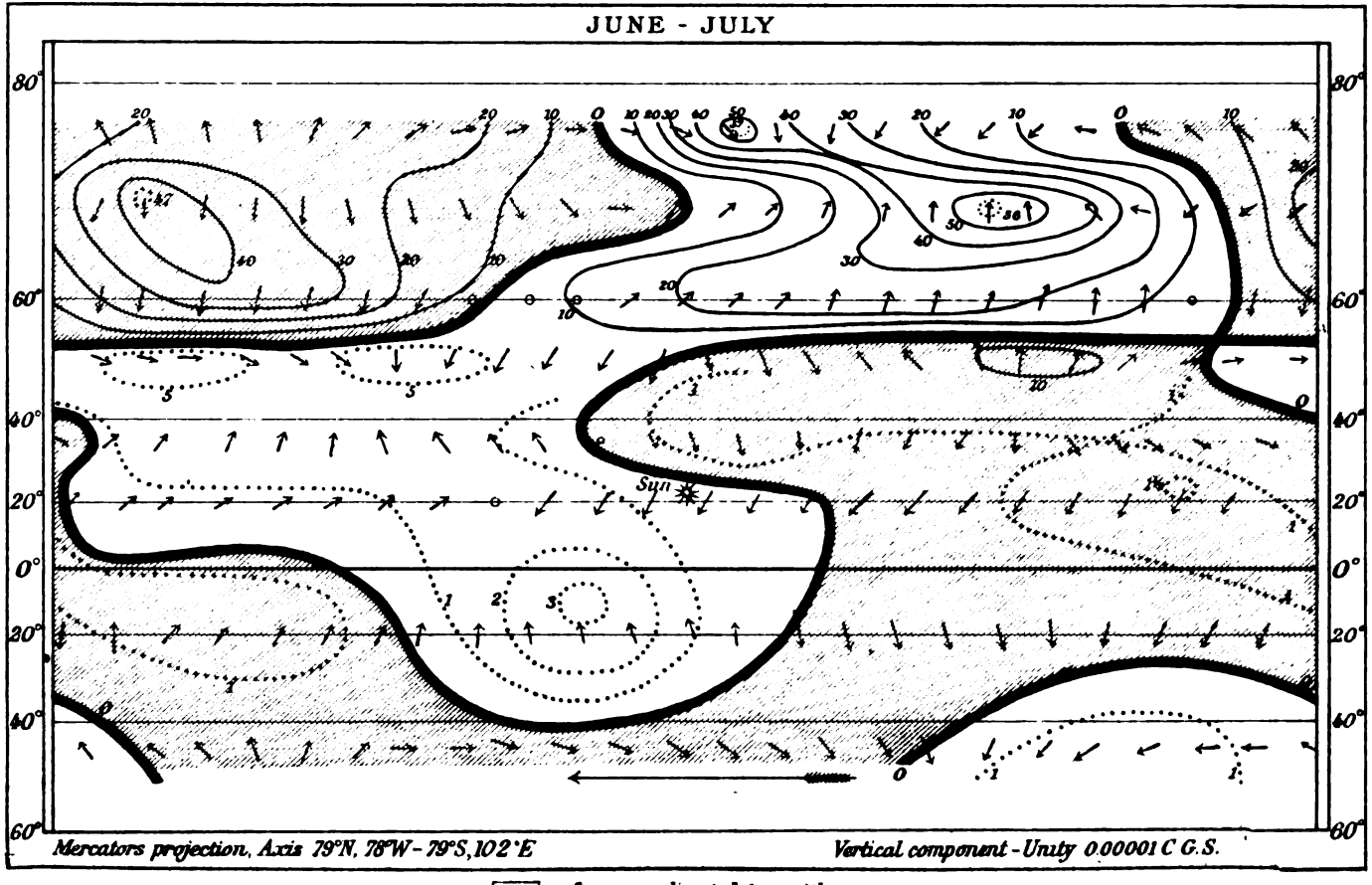
THE NEW YORK
PUBLIC LIBRARY.

ASTOR, LENOX AND
TILDEN FOUNDATIONS

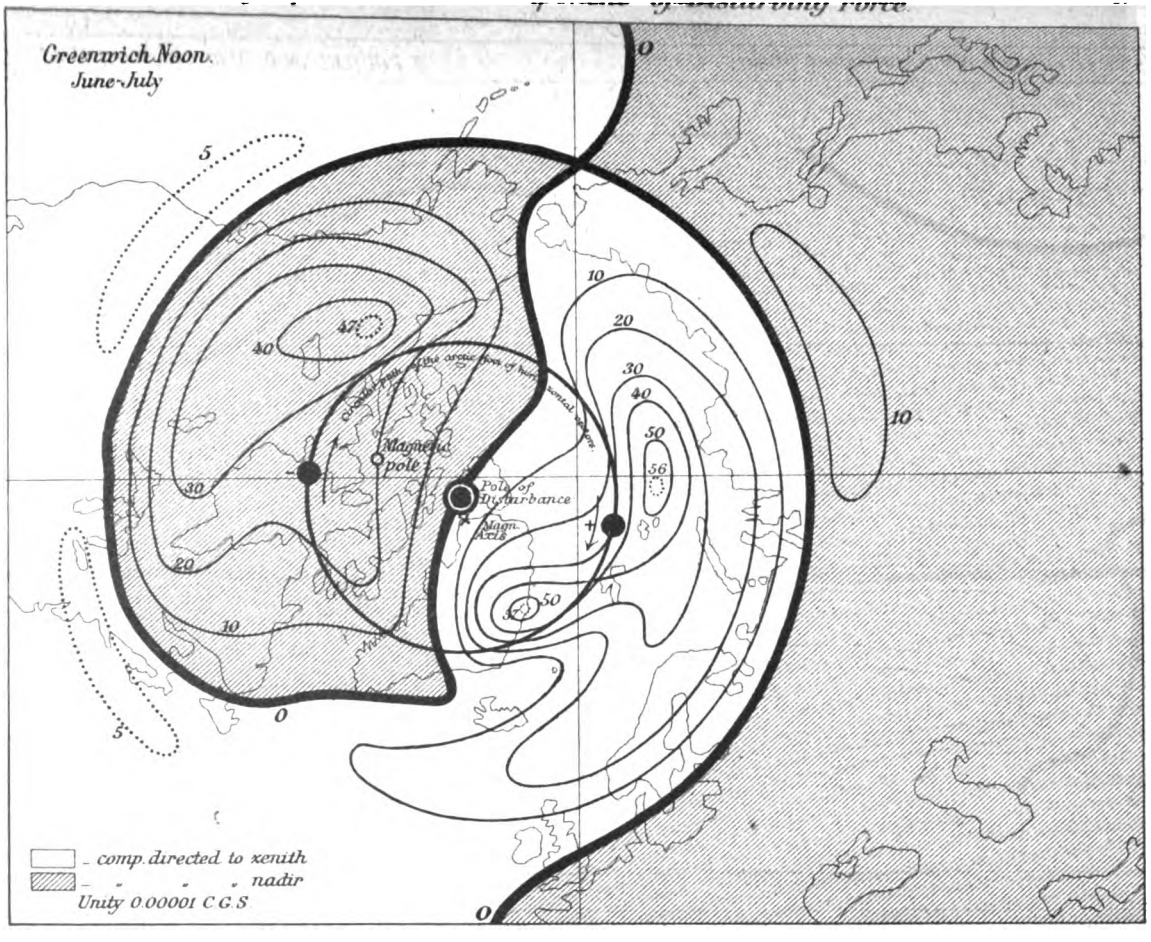
Digitized by Google

Daily Field of Disturbing Force.

Horizontal Vectors and Lines of equal Vertical Component.



Digitized by Google



Digitized by Google

THE NEW YORK

Digitized by Google

seems not improbable that only a single focus exists, which, however, suffers some change during the daily rotation.

The two western foci on the parallel of Greenwich owe their existence to the values of this station only; notwithstanding it seems better to consider both as the two centers of a double focus.

From the foci in southern latitudes the eastern one is partly shown on the map, but the western one is only indicated; the existence, however, of two Antarctic foci, corresponding to the Arctic ones, may safely be accepted.

Considering the directions of the arrows it is obvious, that they point with great regularity towards the positive foci and radiate from the negative ones.

As the Arctic foci can better be represented on a map in stereographic projection, such a map has been constructed and reproduced in the plate (right-hand side). The two foci of the horizontal vectors of the Arctic stations and their circular path, discussed above, have been introduced as well as the pole of disturbance, the north end of the magnetic axis of the Earth and the magnetic pole, in order to make it apparent, how much nearer the pole of disturbance is situated to the former than to the latter.

The positive and the negative focus of horizontal vectors are situated close to the region where the vertical component shows a maximum and a minimum, respectively; the positive one lies between the two maxima, the negative following the minimum.

ON THE CAUSE OF THE DIURNAL FIELD OF DISTURBANCE.

The current view of geophysicists on the fields of force causing the diurnal variation and disturbance is, that they are generated by electric currents flowing above and below the Earth's surface.

If we suppose a current ring to exist outside the Earth in a plane parallel to its surface, then the lines of equal vertical magnetic force on the surface will be concentric with the projection of that ring. In case the ring moves in its own plane, the course of the lines of equal vertical force in regard to the moving projection of the ring will deviate from their original course, in consequence of currents induced in the Earth's crust, in proportion to the rate of motion and the conductivity of the crust.

In case the path of the primary current is not a ring and we are dealing with a system of currents inclosing various centra, the lines of flow will be less and less concentric with those of equal vertical force, the more intricate the system.

Digitized by Google

According to the results obtained in this paper we may suppose as a first approximation, that the daily field of disturbing force is generated by the existence of a system of current rings inclosing eight foci. As the horizontal vectors point to the foci of maximum component, directed to the zenith, this system of currents, according to Ampère's rule, must be situated chiefly outside the Earth.

When a current ring moves centrally over a place, the influence of current induced in the Earth is such, that the extreme value of the vertical component for that place occurs after the moment the center passes, the horizontal component vanishing before this moment. From the representation of the field for the Arctic cap, we may conclude, that the negative focus and the minimum ($-47\ \gamma$) of vertical component are related in a contrary way, the latter preceding the former. For the positive region of vertical component the double focus makes any result ambiguous. In how far this may be understood as an objection to the hypothesis of electric currents is quite uncertain.

Schuster remarks that the course of the equipotential lines of his field of diurnal variation will deviate only slightly from the lines of electric flow, which may be supposed to be the cause of the production of the field. Hence we are allowed to compare directly the lines of equal vertical force drawn here for the field of disturbance, with the equipotential lines of the field of diurnal variation as it has been constructed by von Bezold[1] based on Schuster's calculations.

The most striking difference may be said to be, that the areas of positive and negative potential of diurnal variation are approximately bisected by the meridians of noon and midnight whereas the areas of upward and downward disturbing force are approximately bisected by the line of separation of day and night.

Finally it is to be remarked, that the foci of the Northern Hemisphere are strongest in the summer; a computation for Jan Mayen gives a considerable reduction for winter.

It is indeed desirable to extend the investigation of the diurnal variation field over the polar regions, but in these regions, though the use of quiet days may have great advantage, as shown by Lüdeling in the paper quoted above, the phenomena still remain

[1] *Sitzungsberichte der Akademie zu Berlin*, 1897, p. 271. Tafel III.
See *T. M.*, Vol. IV, p. 48, or Vol. III, p. 111.

Digitized by Google

rather intricate. Besides a day selected in the usual way as a quiet one is not to be considered as entirely free from disturbance.

To prove this 26 couples of successive days for the summer months have been chosen out of the days selected by Wild as quiet ones for Petersburg–Pawlowsk. They are:

1873 June 7— 8	1886 Aug. 22—23	1896 July 23—24
" 22—23	1887 June 14—15	1897 Aug. 27—28
1877 June 2— 3	Aug. 11—12	1898 July 17/18—18/19
" 3— 4	1888 July 13—14	1899 June 6/ 7— 7/ 8
1882 July 14—15	Aug. 10—11	July 28—29
1883 June 4— 5	1890 Aug. 30—31	Aug. 11—12
July 21—22	1891 June 12—13	" 15/16—16/17
" 22—23	1893 Aug. 27—28	" 18—19
" 28—29	1895 June 25—26	

The differences of corresponding hourly values of H and D have been taken for each couple and the mean difference for each hour has been calculated. By means of the latter the diagram of the horizontal differential vector has been constructed, which proved to be quite regular and to rotate clockwise, i. e., in the same direction, which is preponderant in the daily diagram of the disturbing vector. This points to the existence of disturbing vectors during such days as are considered to be undisturbed.

These hourly values, mentioned above, expressed in 0.00001 *C. G. S.* are:

Hour	1	2	3	4	5	6	7	8	9	10	11	Noon
HdD	0.1	0.8	-0.4	-1.1	0.3	0.7	0.1	1.3	2.1	2.5	0.8	1.2
dH	-2.0	-1.2	-1.1	-0.5	-1.6	-2.9	-2.1	-1.1	0.9	2.5	0.5	0.9

Hour	1	2	3	4	5	6	7	8	9	10	11	Midnight
HdD	-0.7	-1.2	-1.7	-1.3	-2.4	-5.1	-1.1	-1.4	-0.7	-0.1	2.2	1.0
dH	1.8	1.4	1.6	2.2	0.3	0.2	-0.6	-4.1	0.1	-1.2	-1.4	-0.9

Dr. Fritsche, in his paper on the diurnal variation of the magnetic elements,[1] has extended the computation of the potential function over the polar regions, but I think his results for these parts of the globe are not trustworthy. He makes use of the data for Arctic stations calculated for all days, taking the average diurnal variation for these stations, divided into two groups, viz., Polhem,

[1]Die tägliche Periode der erdmagnetichen Elemente. *St. Petersburg*, 1902.

Digitized by Google

Cape Thordsen, Ssagastyr, Karmakul, Point Barrow, and Jan Mayen, Bossekop, Kingua Fjord, Fort Rae. From what has been found in this paper with regard to the disturbing phenomenon, it is evident that the diurnal variation derived in the manner stated is different for Arctic and for non-Arctic stations, the result from the former stations deviating strongly from what is understood to be the true solar-diurnal variation. No doubt the great differences in the elements observed at Arctic stations from those calculated by Fritsche are due to his data having been derived without excluding days of disturbances.

Digitized by Google

ATMOSPHERIC ELECTRICITY AND TERRESTRIAL MAGNETISM AT THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE 1903.

By A. Lawrence Rotch.

These topics were more than usually prominent at Southport, on account of the joint meeting of the International Meteorological Committee under the presidency of Professor Mascart, by reason of the interest aroused by Sir Norman Lockyer's paper before the Physical Section of the Association and from the fact that the presidential address to the Geographical Section was delivered by a magnetician.

There were present a majority of the International Meteorological Committee, besides several members of two subcommittees, including the writer. The proceedings, so far as they related to the above subjects, were as follows: The Royal Saxon Academy of Sciences submitted the text of resolutions adopted by the Commission on the Physics of the Globe, regarding the scientific organization of investigations in atmospheric electricity, and it was decided that if these resolutions were approved by the International Association of Academies, the Committee would aid in having the investigations undertaken. Dr. Paulsen, of Copenhagen, exhibited an instrument for collecting atmospheric electricity by radio-active salts. It was voted that Dr. Snellen, who had resigned the directorship of the Royal Dutch Meteorological Institute to take charge of the magnetic observatory at De Bilt, near Utrecht, be authorized to receive and distribute the observations on quiet magnetic days. The question proposed by Rev. J. de Moidrey concerning disturbed days was referred to the magnetic subcommittee. It was announced that Professor Rücker had consented to remain chairman of this committee, which would hold a meeting in conjunction with the British Association at Cambridge in August, 1904.

There was organized a very interesting exhibition of instruments, etc., in connection with the meeting. The Hydrographic Department of the Admiralty showed instruments for observing the magnetic inclination at sea, as used from 1772 until the present time, and also Hansteen's instrument for observing the horizontal force. The Greenwich and Kew Observatories exhibited magnetic records and the last-named institution showed also an early form of Thomson's portable cage-electrometer and an old pattern dip-circle. Captain Creak had on view several charts

Digitized by Google

illustrating the changes in magnetic declination since 1700. Professor Pernter, of Vienna, exhibited the Bendorf self-registering electrometer for atmospheric potential, in which the collector is a copper disk covered with radium bromide.

A large number of diagrams of solar changes and of related terrestrial changes illustrated the communication by Sir Norman Lockyer, already referred to, which it was surmised might form the subject of his address as president of the Association, but which was fortunately presented to the Physical Section where it could be discussed. The paper is reprinted in *Science*, November 13, 1903, the conclusions reached by the author being that solar prominences are not only the primary factors in the magnetic and atmospheric changes occurring in our Sun, but that they are also the inciters of the terrestrial variations.

These views were combated by Father Cortie, of Stonyhurst Observatory, who said that recent researches by Father Sidgreaves, Dr. Chree and himself regarding the relation that exists between Sun-spots and terrestrial magnetism had emphasized the general connection of the phenomena, but had disproved any connection of efficient cause and effect. The results of the inquiries were more consistent with the existence of a common cause which affected the Sun and the magnets on the Earth. The question had been raised some time since by Dr. Garibaldi, and more recently by Sir Norman and Dr. Lockyer, as to whether prominences might not supply the place of Sun-spots in those cases in which a great magnetic storm was unaccompanied by any spot, but it would appear that prominences could not, in general, be isolated from Sun-spots, as phenomena which were particularly active in influencing terrestrial magnetism. The question still remained whether particularly large and violent eruptive prominences might not produce magnetic storms in the absence of spots. A detailed study of individual prominences and magnetic storms for the years of minimum spots, 1887–8, had been made, and out of 48 important prominences, 29 were found to be immediately associated with spots or faculæ, or occurred in spot zones. From the declination observations at Stonyhurst it was found that in only one case was a magnetic storm observed when there was a high prominence, and only nine magnetic disturbances occurred during such periods, allowing three days before and after each observation of a prominence. In no single case could a magnetic storm be connected certainly with any particular prominence.

Two papers by Dr. Bauer, of Washington, were abstracted by Professor Schuster. The first paper dealt with the progress of the magnetic survey of the United States, and stated that Maryland has now the most detailed magnetic survey of any country except Holland. Holland has one station to every 40 square miles, Maryland one to every 100 square miles, and England one to every 139 square miles. By 1910–15 it is

Digitized by Google

planned that there will be, on the average, in the United States one magnetic station to every 600–900 square miles. Five magnetic observatories are in operation. The second paper concerned the Earth's total magnetic energy, for the space outside of the Earth's surface, and it was calculated that there has been a loss of nearly 3 per cent between the years 1838 and 1884, indicating, if true, that the Earth's magnetism is dying out at an alarming rate. As, however, the data on which the calculations must be based appear insufficient, no definite conclusion was reached. The address of the president of the Geographical Section treated this year of terrestrial magnetism, Captain Creak reviewing the development of our knowledge of the magnetic conditions of the globe. The address is published in full in *Nature*, September 24, 1903.

In a paper on cosmical radio-activity, before the Physical Section, Professor Schuster asked whether radio-activity is not, like magnetism, a common property of all matter, enormously exaggerated in certain substances. The question arose whether the effect would be cumulative and should appear in the cosmic aggregations of matter. Like the Sun and the neighborhood of a radio-active body, the Earth is charged with negative electricity, and this charge must constantly be renewed, as the leakage due to the spraying of ocean waves and the hot gases escaping from chimneys would ultimately dissipate the charge. According to Elster and Geitel 1⅓ per cent of the charge was lost per minute, so that, if the air in the neighborhood of the ground had this conductivity, the Earth would lose its negative charge in an hour. We are living, therefore, in an electric field through which negatively charged particles (cathode rays) are constantly driven outward and which possesses an electric conductivity similar to that found in the neighborhood of radio-active bodies. The similarity of the rays of the solar corona to cathode rays has often been pointed out, and Professor Schuster has long maintained that the assumption of an increased conductivity of space at the time of a Sun-spot maximum would explain the connection between Sun-spots and terrestrial magnetism.

A paper by Messrs. Elster and Geitel, of Wolfenbüttel, Brunswick, on radio-active emanations in the Earth's crust and atmosphere, was presented in abstract by Dr. Lees. The authors have carried on in Wolfenbüttel, since 1899, continuous observations on the dispersion of atmospheric electricity, and periodical observations all over Europe under the most varied conditions. The dispersion of atmospheric electricity, which is high in caves, seems to be connected with the degree of ionization and with the radio-activity of certain emanations from the soil. If the radio-activity on the sea-coast is 1 then it is 4 at Wolfenbüttel and 30 in the Alps.

Dr. W. J. S. Lockyer exhibited photographs of lightning to illustrate the different types observed—ramified, stream, multiple dark-flashes, etc.,

Digitized by Google

and of the few spectra of lightning so far obtained. The first-order spectrum is characterized by two bright lines and several fainter ones and also some dark lines, and Dr. Lockyer is inclined to favor the assumption that the lightning-spectrum is simply the air-spectrum, as was asserted by Professor Pickering, who first obtained the spectrum of lightning.

Dr. Paulsen, in a paper on a comparison of the spectrum of nitrogen and the aurora borealis, described the results of the investigation by the Danish Commission in Northern Iceland during 1899–1900. Two spectrographs were used—a French one, consisting of an Iceland-spar prism and quartz lenses, and the other of German construction, with flint lenses and a prism of higher luminous power, which photographed down to the line *O* of the solar spectrum. Twenty-three lines were photographed, under great difficulties, of which sixteen were unknown. Measurements were made on the spot, and, later, by comparison with the cathode glow and spark discharges. Most of the auroral lines agree with the nitrogen lines, but the principal auroral line does not.

Through the courtesy of Professor Schuster a few physicists and meteorologists were shown his laboratory in the Owens College, Manchester.

Blue Hill Meteorological Observatory.

Digitized by Google

EARLY HISTORY OF THE MARINER'S COMPASS AND EARLIEST KNOWLEDGE OF THE MAGNETIC DECLINATION ACCORDING TO BERTELLI.

By D. L. Hazard.

I. THE EARLY HISTORY OF THE MARINER'S COMPASS.[1]

As early as 1866 P. Timoteo Bertelli began the study of the origin and early history of the mariner's compass. The results of his investigations were published in detail in 1893 in a paper entitled "Studi storici intorno alla bussola nautica." His conclusions met the approval of most scientific men; but there were some prominent men in Italy who took exception to his views as to the compass being of Chinese origin and who maintained that the compass was invented as well as perfected at Amalfi, Italy. Bertelli's later contributions to the subject, in reply to these opponents, present the results of his more recent investigations, and treat some phases of the subject in greater detail than was the case in the earlier publications. His conclusions are presented under four general heads.

1. A careful examination of the writings of more than seventy Greek and Latin authors covering the period from the sixth century B. C. to the tenth century A. D. failed to find any mention of the directive property of the lodestone, nor any suggestion from which one might conclude that this directive property was used either in navigation, astronomy, or surveying during that long period of time, though there are numerous descriptions of voyages and storms at sea, where mention of the compass would be expected, if it had been in general use at the time. Apparently the only facts about the lodestone which were known at that time were its property of attracting iron and of communicating that attractive power to iron. That the property of polarity was unknown before the tenth century is shown by the fact that Pliny and subsequent writers explained the phenomena of attraction, repulsion, and neutralization of magnetic action by ascribing them to three supposedly different minerals, *magnete*, *teamede*, and *adamas*. Another circumstance supporting the conclusion that the compass was not used in the Mediterranean before the tenth century, is the fact that all the early descriptions of it which we have (by Neckam, Guyot, etc.) speak of it as a new and wonderful thing.

[1] Sulle recenti controversie intorno all'origine della bussola nautica. P. Timoteo Bertelli, Roma, 1902. lg. 8°, 52 pp.

La Leggenda di Flavio Gioia, inventore della bassola. Osservazioni del P. T. Bertelli, Barnabita, Firenze, 1903, 8°, 28 pp.

Digitized by Google

2. Leaving out of account everything which appears exaggerated or doubtful, it can not be denied that the directive property of the magnet was known to the Chinese before the beginning of the Christian era. In various Chinese and Japanese writings there are repeated descriptions of the so-called south-pointing carts, of which the distinctive feature was a doll attached to a magnet and mounted on a pivot, so that an outstretched arm was always directed toward the south. For instance, the Japanese history (Nip-pon-ki) gives an account of the first use of one of these carts in Japan in 658 A. D., and relates that in 666 A. D. one was presented to the emperor by a Chinese Buddhist priest. In fact these carts seem to have been reserved for the use of the emperors almost exclusively. There is also mention in Chinese books now generally accepted as authentic, of the early use of a rude compass with floating needle. As China looked upon all other nations as barbarians and therefore had no desire to enter in commercial nor political relations with them, her commerce was confined almost entirely to her own rivers and coast. There was therefore very little need for a compass, and probably very few vessels were provided with them. For that reason, also, there was no incentive for improving upon the original form of compass, and it was still in use by the Chinese even after the first voyages of the Portuguese to China.

3. One of these crude compasses with floating needle, as used in some Chinese vessel, was probably introduced into the Mediterranean by the Amalfians about the tenth century. There appears to be no direct evidence on this point, but as the Amalfians were very enterprising and were permitted by the Arabian Government to traffic with the extreme East, it seems not at all improbable that on some voyage a compass was brought home as a curiosity. They soon improved upon it by substituting a pivoted needle for the floating one, and by adding the graduated "Rose of the Winds" which moved with the needle. From Amalfi the use of the compass spread gradually to other parts of the Mediterranean and to the seas of the North.

The first European writer to mention the primitive compass with floating needle was the English monk Alexander Neckam, toward the end of the twelfth century. Peregrinus first describes the compass with pivoted needle, in his famous Epistola, written in 1269. Benjamin ascribes to him the invention of this improvement of the compass, but Bertelli concludes that the pivoted compass was in use as early as the end of the twelfth century.

4. The names of the various persons who between the tenth and fourteenth centuries introduced and perfected the compass are all unknown, and there is no foundation for the tradition which ascribes to a certain Flavio or Giovanni Gioia the invention and important improvements of the compass about the beginning of the fourteenth century.

Digitized by Google

This tradition appears to have originated during the last half of the sixteenth century, since a careful scrutiny of the writers of that and the preceding century who wrote about the compass failed to find any mention of the name of the inventor before that time, most of them stating that his name was unknown. The first writer to refer to the *first* use of the compass in the Mediterranean was the learned Flavio Biondo, who, about 1450, made a first attempt at a history of Italy. Speaking of the compass he says: "Sed fama est qua Amalphitanos audivimus gloriari, magnetis usum, cujus adminiculo navigantes ad arcton diriguntur, Amalphi fuisse inventum, quidquid vero habeat in ea re veritas, certum est id navigandi auxilium priscis omnino fuisse incognitum."

Giovanni Battista Pio, in his "Commentaries on Lucretius" (edition of 1511), makes the following remark in regard to the lodestone: "Amalphi in Campania veteri magnetis usus inventus a Flavio traditur: cuius adminiculo navigantes ad arcton diriguntur: quod auxilium priscis erat incognitum." By comparing this with the passage given above it will be seen that Pio quoted almost word for word from Flavio Biondo and in the clause "a Flavio traditur," he gives Flavio as his authority. Giambattista della Porta, also, in his "Magia Naturale" (First edition, Naples, 1589), uses almost the same words in referring to the origin of the compass, but leaves no doubt as to his meaning when he says, "*ut* a Flavio traditur." Giraldi, however (apparently from a misinterpretation of the passage from Pio, quoted above), gives the credit for the first use of the lodestone as an aid to navigation to an Amalfian named Flavius; for he says: (1580) "Amalphis in Campaniae oppido antiquis navigandi usus incognitus per magnetem et chalybem, quorum indicio nautae ad polos diriguntur, a Flavio quodam excogitatus traditur." Giraldi was the first writer to give the name Flavio to the inventor of the compass, and it is to him that the beginning of this erroneous tradition can be traced. Many writers subsequent to the fifteenth century have either left the question in doubt or have stated positively that the name of the inventor is unknown. Indeed, Lipenio, after mentioning the authors who ascribe the invention to a certain Flavius, says: "Boni isti viri inventoris et scriptoris nomina confundunt; Flavius enim non inventor erat, sed scriptor.

Bertelli shows that Mazzelli, who first (1586) gave Flavio di Gioia as the name of the inventor, and Ortelio, who (1596) used the name Giovanni Gioia, are both untrustworthy historians, at least in what they have to say about the compass. Of later writers, some have used one name and some the other, while some have given credit for the *invention* of the compass to Flavio, and for its *improvement* to Giovanni Gioia. Bertelli concludes, therefore, that there is no foundation in fact for the tradition which ascribes to a particular individual the invention or improvements of the compass.

Digitized by Google

II. WAS THE MAGNETIC DECLINATION KNOWN TO THE CHINESE BEFORE THE TIME OF COLUMBUS?[1]

Some writers maintain that the fact that the compass needle does not in general point exactly to the pole of the heavens was known to the Chinese several centuries before its discovery by Columbus. In evidence of this they cite passages, of which the context is nearly the same, from two Chinese books; "Pen-thsao-yan-i," a natural history of the early part of the twelfth century, and "Mung-khi-po-tan," of about the same epoch, discovered and translated by Stanislaus Julien. The passage from the latter reads as follows: "The soothsayers rub a needle with the lodestone; it will then indicate the south. It declines constantly a little to the east, however; it does not indicate the south exactly. When this needle floats on water it is much agitated. If the finger-nails touch the edge of the basin in which it floats it is very much disturbed; it continues to slide, however, and easily falls to the bottom. In order to show its (directive) property to best advantage it should be suspended in the following manner: Take a single thread from a new skein of cotton and fasten one end of it to the exact middle of the needle by means of a bit of wax as small as a mustard seed. Suspend it in a place where there is no wind, and the needle will then continuously indicate the south." The other passage adds "that if the needle be made to float on water by means of a bit of reed, it will also show the south, but always with a declining toward the point 'ping.'" Ping is the first point to the east of south, each point being 15°.

Bertelli takes exception to the conclusion that these passages show a knowledge of the magnetic declination by the Chinese of that early day. He points out that in both passages it is clearly stated that the property of the needle is best shown when the needle is suspended by a fiber, and that then it points to the south, as though the writers considered its failure to point exactly south when floated to be due to the inferior method of suspension. This was the interpretation adopted by Biot, and he therefore concluded that the declination was very nearly zero at that time in China. Bertelli ascribes the "declining" of the needle when floated to the surface tension of the water, which would prevent the needle from turning freely under the influence of the horizontal component of the Earth's magnetic force. This would not account for its always declining to the east of south, however.

If the Chinese had known of the declination as early as the twelfth century, it is reasonable to presume that the knowledge would have

[1] Della declenazione magnetica presso i Cinesi. P. TIMOTEO BERTELLI, Roma, 1903, 8°, 10 pp.

Nuova conferma che la declinazione magnetica era ignota ai Cinesi prima di Cristoforo Colombo. P. TIMOTEO BERTELLI, Pavia, 1903, 8°, 6 pp.

Digitized by Google

been handed down from generation to generation. We find, however, that when at the beginning of the seventeenth century the Jesuit mathematician and astronomer, Matteo Ricci, and some of his fellow-missionaries were allowed by the emperor of China to take part in the so-called Tribunal of Mathematicians, it was with great difficulty and only by ocular demonstration that they were able to convince the Chinese scientists that the magnetic and astronomic meridians are not coincident. At that time the declination at Peking was about 2° west, as determined by Ricci. Nearly two centuries later Amiot found that the Chinese still assumed the declination as 2° west in placing their sun-dials, showing that the knowledge of the fact was preserved for two centuries after its demonstration by Ricci.

Bertelli concludes, therefore, that Columbus and not the Chinese, was the discoverer of the magnetic declination.

Digitized by Google

LETTER TO EDITOR

REQUEST FOR LIST OF MAGNETICALLY CALM DAYS.

Le 9 Septembre 1903 le Comité réuni à Southport, a résolu:

1. Que M. Snellen sera chargé de recevoir et de distribuer les observations sur les jours calmes, et
2. Que la question des jours troubles (proposée par Rév. J. de Moidrey) sera remisa à la Commission magnétique.

Par conséquent, vous êtes prié à envoyer dès à présent les observations sur les jours calmes directement à *Monsieur M. Snellen,*
Chef du Service magnétique à De Bilt près Utrecht, Holland

H. HILDEBRAND HILDEBRANDSSON,
Upsal, le 30, Septembre, 1903. Le Secrétaire,
Comité International Météorologique.

Digitized by Google

THE MAGNETIC ELEMENTS OF FORTY-FOUR STATIONS IN MADAGASCAR, DETERMINED BY PROF. P. COLIN, DIRECTOR OF THE TANANARIVE OBSERVATORY.

J. W. FROLEY.

The magnetic elements of the first thirty-six stations given in the table were communicated by Prof. Colin to the *Comptes Rendus* for June, 1902. On application to him for information as to the positions of the stations, he sent me a French Army chart with these thirty-six stations and eight additional ones plotted thereon. The co-ordinates ot he positions were expressed in grades which have been reduced to degrees and the origin of longitudes has been transferred from Paris to Greenwich. The longitudes of all the stations are made to depend on that of Tananarive Observatory as given by French Hydrographic charts.

In a discussion of the observations Prof. Colin notes that there are striking anomalies at several places which he terms centers of perturbations. First, at Tsiafajavona, the highest peak of the chain of the Ankaratra, the needle, instead of pointing N. N. W., points N 3° 15′.8 E; the inclination, which should be about 54° 30′, falls to 47° 45′.2. The Ankaratra by virtue of its mass and altitude, exercises considerable influence on the surroundings. At distances removed considerably from the eastern side of the plateau toward Andraraty, Amhatolampy, Antsiriribé and Morarano, the three elements return to their ordinary values.

A second center of perturbation, less distinct than that of the Ankaratra, is in the neighborhood of Vontovorona. The anomaly begins with a minimum of the three elements at Antanifotsy, south of Morarano; then the declination and inclination increase until Soandrarina is reached; at the latter place the intensity drops 0.004 *c. g. s.* below the normal. The reverse takes place on the summit of Vontovorona, viz: decrease in declination and inclination and increase in intensity.

On the other side of Vontovorona extends a volcanic zone. The difference in declination between the two stations at Antsirabé, 300 meters apart equals 9′. Between Antisirabé and Betafo, the difference in declination is a half degree, and the intensity decreases by 0.004 as at Soavinandriana.

North of Betafo at Tokotanitsara there appears a remarkable discordance in the declination which is N. 38° 18′.5 W. The needle is deflected by the solid mass of basalt of the Vavavato, which is 2 km. to the Westward. At the three stations near this chain, Antanifotsy, Manaribefona, and Belamosina, the three elements increase gradually.

Digitized by Google

On the edge of the crater lake of Vinaninony, at Tsarazafy, anomalies in the horizontal component exhibited themselves.

The irregularity in the intensity and in the declination is shown still more on the summit of Ambohipoloalina.

At Dango, the declination decreases, the intensity increases; a comparison of Faratsio and Raimainandro shows values nearly regular, slightly increased, however, by the proximity of the Ankaratra a disturbance extends to these stations. At Andakandrano the needle resumes its normal direction. At Ampefy on the edge of the crater lake the declination is a minimum for that region, and it is a maximum on the ancient volcano of Ambasy. The value of the horizontal component becomes less in this last place, and greater at Soavinandriana. The inclination is a little large at Ampefy and at Soavinandriana.

The disturbing influence discontinues where the volcanic zone terminates. At Ambohimiangara and Miarinarivo, the distribution of the magnetic forces appears uniform. A slight decrease in declination is indicated at Arivonimamo, due probably to the attractive influence of the neighboring mountain Ambohimpanompo.

In conclusion Prof. Colin observes, that in the central uplift in Madagascar, the magnetic perturbations extend furthest and affect most the ridge of the Ankaratra to Vontovorona as well as the ramifications of the uplift of the Vavatao, that the eastern plateau which borders the foot of this ridge has a magnetic field of greater regularity than the western plateau; that the volcanic zones have a local influence of small extent.

U. S. HYDROGRAPHIC OFFICE, WASHINGTON, D. C.

Digitized by Google

	Place	Latitude S.	Longitude E of Gr	Date 1901	Declination	Dip South	Hor'l Int.	Description of Station	Character of the Surface Soil.
		° ′ ″	° ′ ″	Sept.	° ′ ″	° ′ ″	γ		
1	Andramasina	19 11.0	47 56.8	10	9 25.7 W.	. . .	. . .	Outside of village, close to cemetery.	Red clay mixed with humus.
2	A^{ni}mahavony	19 18.8	47 39.9	11	14 48.3 "	. . .	. . .	On plateau, near a monument.	Red clay.
3	Antanamalazakely	19 24.7	47 41.7	11–12	10 22.3 "	54 42.9	. . .	Near rock, in middle of plateau.	Clay mixed with humus; granite.
4	Tsinjoarivo	19 38.2	47 44.8	12	10 39.0"	54 40.5	25152	Center of court, old manaion.	Reddish colored clay.
5	Sarobaratiakely	19 36.2	47 36.8	13	10 51.3 "	. . . .	. .	Near monument, emblem, idolatry.	Auriferous, quartzy earth, containing iron.
6	Antsiriribé	19 36.0	47 31.8	14	11 04.3 "	. . .	25069	North of village, at end of walk.	Red clay.
7	Ambatolampy	19 22.6	47 28.0	15	10 49.7 "	54 45.1	25161	On plaza, near executive offices.	Clay, large granite rocks to westward.
8	Andraraty	19 21.9	47 22.0	17	10 28.4 "	54 34.0	25062	Near ditch, S. W., of village.	Red clay.
9	Tsiafajavona	19 21.0	47 16.8	18	3 15.8 E.	47 45.2	. . .	Peak, near geodetic station.	Volcanic rocks (Néphélinite basaltique); influential on the magnet.
10	Morarano	19 32.2	47 21.9	19	11 06.0 W.	54 54.8	25066	Close to Catholic Church.	Red clay.
11	Antanifotsy (East)	19 39.5	47 22.4	20	10 36.7 "	54 50.4	24944	On plateau, near Church.	Red clay.
12	Betampona	19 48.0	47 19.3	21	10 48.8 "	55 18.2	24724	On plateau, N. W. of village.	Red clay; to northward, rocks of a cellular texture.
13	Soandrarina	19 54.2	47 16.7	22	12 49.6 "	56 22.8	24339	Near monument, west of village.	Grayish colored clay.
14	Vontovorona	19 54.4	47 15.4	23	10 32.2 "	50 14.5	24633	Peak, near geodetic Station.	Ancient volcano of conical form. (Trachyte phonolitique), slightly magnetic.
15	A^{mo}dranandriana	19 53.2	47 12.8	23	12 09.9 "	. . . .	. . .	North of the village.	Alluvium soil; marl, quartz.
16	Antsirabé	19 52.9	47 05.0	24	11 14.6 "	55 38.5	24732	Center of garden of Catholic Mission.	Yellow clay; soil of volcanic origin.
16a	" (Hot Spring)	. . . .	. . . .	25	11 23.6 "	. . . .	. . .	By cistern, north of hot spring.	Trachytes, basalt, calcareous concretions; peat.
17	Betafo	19 50.3	46 55.0	25–26	11 44.3 "	55 47.7	24318	On plaza, 200 meters north of Catholic Mission.	Volcanic earth; volcanic ashes.
18	Iavoko	19 51.2	46 57.1	26	12 03.9 "	. . . .	. . .	On summit of little hill.	Ancient volcano notched; on east side strong flow of lava. (Scories basaltiques).
19	Antanifotsy (West)	19 41.4	47 00.9	28	10 41.4 "	55 00.6	24812	500 meters east of village.	Rose colored clay; volcanic rocks to the west (basalt much changed, a little magnetic).
20	Manarilefona	19 39.0	47 01.6	28	10 52.6 "	. . . .	24890	100 meters west of village.	Yellow clay; large rocks to the eastward.
21	Tokotanitsara	19 38.7	46 58.9	29	38 18.6 "	. . . .	. . .	2 meters east of edge of plateau.	Volcanic rock; scorie basaltique, magnetic.
22	Belamosina	19 35.4	46 58.3	29–30	11 48.5 "	55 23.2	25202	100 meters south of village.	Red clay; burnt rock in the neighborhood.
23	Tsarazafy	19 33.2	46 59.2	30	12 21.2 "	53 11.6	24845	60 meters N. E. of village, on spur of hill.	Crater lake of the ancient volcano, trachyte augitique; magnetic, quartz; yellow clay,
				Oct.					
24	Faratsio	19 23.3	46 59.8	1	11 04.6 "	54 51.3	25033	In field south of Catholic Church.	Gray colored clay, quartz.
25	A^{mo}poloalina	19 23.1	46 57.1	2	15 35.7 "	. . . .	19337	Near geodetic signal.	Black soil; trachyte phonolitique; magnetic; burnt rocks; quartz; lignite to the northwest.
26	Andakandrano	19 17.8	46 52.9	3	10 46.8 "	. . . .	. . .	150 meters N. W. of village.	Red clay, very micaceous; quartz.
27	Dango	19 17.3	46 55.0	3	14 54.4 "	. . . .	24512	Peak, east of masonry work, close to rock.	Large hill with four lakes.
28	Ramainandro	19 17.9	47 03.4	3	11 05.2 "	54 31.1	24984	Above village, below Governor's garden.	Light colored soil; granite; quartz; in the valley hot springs; volcanic.
29	Soavinandriana	19 09.6	46 47.9	4–5	10 40.3 "	55 32.8	24655	In middle of plaza, north of village.	Volcanic ashes, basalte limburgitique, magnetic; 6 kilometers southwest of ancient volcano; 12 kilometers to hot springs; frequent trembling of the earth.
30	Ambasy	19 05.9	46 47.4	5	11 43.2 "	. . . .	24388	On summit, close to pile of rocks.	Ancient volcano of conical form; scorie basaltique, magnetic.
31	Ampefy	19 02.8	46 47.3	5–6	9 25.6 "	54 57.9	. . .	Near the gate, north of village.	Alluvium soil, on the edge of the crater, Lake Itasy.
32	A^{ni}miangara	18 59.9	46 55.0	6	10 32.2 "	. . . .	25358	Near geodetic signal.	Soil covered with fragments of quartz. Primitive mica much altered. non-magnetic.
33	Miarinarivo	18 57.2	46 57.4	6–7	10 30.6 "	53 51.6	25236	Garden of Catholic Mission.	Reddish clay.
34	Sohamanina	18 59.4	47 03.2	7	. . . . .	58 55.8	. . .	On high road, S. E. of village.	Red clay; 1 kilometer south and east, abundant iron ore.
35	Arivonimamo	19 00.5	47 13.6	7–8	9 56.3 "	53 45.8	25604		
36	Tananarive (Observ.)	18 54.8	47 36.2	16–19 1902 April	10 19.9 "	53 56.3	25779	In field, 100 meters north of Catholic Normal School. New magnetic pillar.	Red clay; 1.5 km. to the east, large granite rocks; in the vicinity of volcanic rocks. Red clay; hunk of gneiss.
37	A^{ni}mpanompo	18 59.9	47 16.5	12	13 51.5 "	. . . .	24383	Near geodetic signal.	Granite rocks.
34	Sohamanina	18 59.4	47 03.2	13	6 18.0 E.	54 54.2	25069	Near gate, S. W. of village.	Iron ore.
38	Amboanana	19 07.9	47 13.8	14	10 39.0 W.	53 59.7	24846	Plaza, north of village.	Red clay.
39	A^{ni}fohitrimo	19 05.9	47 05.4	15 Sept.	10 21.0 "	54 20.6	25005	On road, 200 meters south of village.	Red clay.
40	Behenjy	19 12.7	47 32.6	22	. . . . .	54 42.6	. . .	Near the commissary headquarters.	Red clay.
41	Ambatolampy	19 22.6	47 28.0	23–54	10 36.1 "	54 53.1	24827	10 meters west of position for 1901.	Clay, granite rock to the west.
42	Miantsoarivo	19 11.9	47 27.6	25	9 48.1 "	54 17.0	25434	60 meters N. W. of Catholic Mission.	Red clay.
43	Fehibé	19 08.5	47 23.0	26	11 01.6 "	55 42.1	24599	Plaza, center of village.	Burnt rocks; vicinity of flint cinders; reddish yellow clay.
44	Tsizangaina	19 05.6	47 27.3	26–27	10 37.7 "	54 16.6	25358	North Gate, Catholic Mission.	Red clay; granite mountain northwest.

Digitized by Google

NOTES

16. *The Great Magnetic Disturbance of October 31, 1903.* A number of interesting reports have been received from various sources, the publication of which will be deferred until the next issue when a brief summary can be attempted of what has become known thus far with reference to this disturbance, as also a tabulation given of the notable disturbances and of allied phenomena during 1903.

Since October 31st, notable disturbances occurred December 13th–14th, and December 29th–31st.

17. *Corrigendum.* *M. Moureaux* informs the Editor that the set of field instruments used by him in his magnetic survey of France was not designed by him, as might be inferred by the appellation, "Moureaux-Chasselon," used on pp. 63 and 64 of the June issue of the Journal in referring to the large corrections due to the impurity of the brass found in a set of these instruments purchased by the Coast and Geodetic Survey. The dip circle was designed by *M. d'Abbadie* and the magnetometer by *M. Mascart* and the first sets were constructed by *M. M. Brunner.*

18. *Magnetic Survey of South Africa.* *Professor J. C. Beattie* writes that "the magnetic survey of South Africa is going on fairly well. Observations have already been made at over three hundred stations between Cape Town and the Zambesi, and it is hoped to observe at about one hundred and fifty more stations."

"*Father Goetz* at Bulawayo has agreed to do what he can in Rhodesia.

"We hope very much to get permanent stations at Bulawayo, Bloemfontein, Cape Town, and perhaps also in the Transvaal and in Natal."

In the interest of magnetic science in the Southern Hemisphere, we must congratulate Professor Beattie upon what he has already accomplished and trust that his efforts to secure the erection of some magnetic observatories will also be crowned with success.

19. *The Bahama expedition of the Baltimore Geographical Society* under the leadership of *Professor G. B. Shattuck*, of the Johns Hopkins University, secured some valuable magnetic data, in the Bahamas during June and July of this year. The observations were made by *Dr. O. L. Fassig*, section director of the U. S. Weather Bureau at Baltimore with a set of instruments loaned by the Coast and Geodetic Survey, in which Bureau the observations are being reduced; the results will be communicated later.

Digitized by Google

20. *Observatoire de l'Ebre.* From a manuscript report by *Father R. Cirera, S. J.*, kindly put at the disposal of the Editor by *Father Hagen*, in charge of the Observatory of the Georgetown University, the following facts are extracted: Plans have been formulated for the erection of an observatory equipped with magnetic, astronomical, meteorological and atmospheric electricity instruments for the general investigation of problems in cosmical physics. It will be situated near Tortose, in the eastern part of Spain, near the mouth of the river Ebre; the geographical coordinates are approximately 40° 48′ latitude and longitude 1° 47′ west of Paris, or 0° 33′ E. of Greenwich. The principal instruments are under construction and it is hoped that the work can be begun at the end of 1904. The magnetic instruments will be a Mascart magnetograph and eye-reading set, Kew magnetometer for the absolute observations and an earth-inductor.

The site appears to be a well-chosen one, free from any disturbing influences of whatever kind. It is in the vicinity of the Jesuit College and will be in the shadow belt of the total solar eclipse of 1905.

21. *Magnetic Observatory at De Bilt, near Utrecht.* We regret to be informed of the loss, by fire, of the variation observatory and that, owing to projected electric car lines, the immediate restoration of the observatory can not be undertaken.

22. *Van Bemmelen's publications.* Dr. W. van Bemmelen has deposited with the bookseller, Martinus Nyhoff, The Hague, Holland, a limited number of copies of the following two publications: "Die Abweichung der Magnetnadel, 1899," "Die säculare Verlegung der Magnetische Axe der Erde, 1900." These copies are for sale. Scientific persons and libraries, however, can procure copies gratis by corresponding directly with Dr. van Bemmelen, Magnetic Observatory, Batavia, Java.

23. *Magnetic Observatory in the Samoan Islands.* In accordance with the information courteously supplied by Professor Wiechert, it is proposed to carry on the work of this observatory, established under the auspices of the Academy of Sciences, Göttingen, until April, 1904. The variation observations were begun early in 1903, the magnetograph being of the Eschenhagen design. The Observatory is situated at Apia.

24. *Magnetic Observatories in the Argentine Republic.* Two magnetic observatories will soon be in full operation in the Argentine Republic, one in the vicinity of Cordova and the other on the island, "Año Nuevo." (See frontispiece.) Fuller details will be given in a future issue.

25. *Peculiar changes in the secular variation in the United States.* Recent observations by the United States Coast and Geodetic Survey have revealed some curious and unexpected secular changes in the magnetic elements occurring in certain parts of the United States. For example, in Maryland it would appear as though the dip diminished at the rate of about 1½′ from 1896 to about 1900, and then increased about

Digitized by Google

the same amount so that the dip measured in 1903 exhibits hardly any change over that obtained in 1896 by L. A. Bauer when conducting the magnetic survey of Maryland.

In the South-Middle States, e. g., Kentucky, Mississippi, Louisiana, Texas, Missouri, Kansas, where east declination should be *decreasing at the average rate of about 3′ per annum*, the recent reoccupation of stations previously observed at by the Coast and Geodetic Survey, shows in some regions an *increase* instead of a decrease, and in other regions a diminished rate of decrease.

In other parts of the United States the "repeat" observations give annual changes agreeing, in general, well with the lines of equal annual change laid down on the isogonic chart of the United States for 1902.

It is rather curious to note that the anomalous changes are going on mainly in the region where the departures of the magnetic elements from the values which they would have on the basis of a uniform magnetization of the United States are most pronounced (See T. M., Vol. V, pp. 1–4). In this region, furthermore, there have been of late certain seismic disturbances which have not always been recorded on *seismographs* but have been recorded on the *magnetograph* at the Cheltenham Magnetic Observatory.

It is therefore evident that we have here local causes acting which affect the normal course of the secular variation. [Some instances of the disturbing action of local causes in the secular variation were cited by Captain Creak in his vice-presidential address before the Section of Geography at the recent meeting of the British Association.]

26. *Continuance of Special Rapid Registration Observations.* The five Coast and Geodetic Survey magnetic observatories will continue during 1904 the special rapid registration observations at the following times:[1]

Greenwich mean civil time.	h.	h.	Greenwich mean civil time.	h.	h.
January 1, . . .	21½	23½	April 1, . . .	3½	5½
" 15–16, . . .	22½	0½	" 15, . . .	4½	6½
Jan. 31–Feb. 1, . . .	23½	1½	May 1, . . .	5½	7½
February 15, ...	0½	2½	" 15, . . .	6½	8½
March 1, ...	1½	3½	June 1, . . .	7½	9½
" 15, ...	2½	4½	" 15, . . .	8½	10½

etc., through the entire year.

[1]See T. M., VIII, p. 74.

Digitized by Google

ABSTRACTS AND REVIEWS.

SCHUSTER, A. ON SOME DEFINITE INTEGRALS AND A NEW METHOD OF REDUCING A FUNCTION OF SPHERICAL CO-ORDINATES TO A SERIES OF SPHERICAL HARMONICS[1].

This investigation deals with some definite integrals useful in expressing a function of two angular variables by means of a series of spherical surface harmonics. An important theorem is deduced, rendering it possible to determine the Gaussian coefficients of the various harmonic terms in the expression of the Earth's magnetic potential, independently of one another. In the methods hitherto employed, the values of the coefficients of the higher harmonics have depended upon the number of terms used. The author reserves for a future paper, the comparison of the values of the coefficients as obtained by his method, with those of previous computers.

Although we must be thankful to the author for his interesting and valuable contribution to the methods of analyzing the magnetic condition of the Earth, it is questionable whether, at the present stage of our knowledge of the distribution of the Earth's magnetism, any great, *absolute* gain will result. The fundamental step to be taken is, the amassing of homogeneous data fairly uniformly distributed over the zone from about 60° N. to 60° S. L. A. B.

[1] *Phil. Trans. R. S.* Ser. A, Vol. 200, pp. 181–223.

LYONS'S TREATISE ON ELECTRO-MAGNETIC PHENOMENA.[1]

This volume, the second and last of the treatise, fulfills in part the hopes that were aroused by Volume I. The author's experience, and his informal, often clever, style, find here opportunity to unite in producing a semi-popular work on the compass as used in navigation, interesting alike to the mariner, and the layman. To those looking for scientific accuracy, however, the book is likely to prove interesting in a way not intended by the author. It offers an even more varied collection of mis-statements than its predecessor, and the lover of scientific curios would do well to turn its leaves.

It is unfortunate that a book containing the possibilities of such real merit should be so fatally marred, and still more unfortunate that it will doubtless be received by many, both here and abroad, as an example of contemporary American scientific writing. Most of the criticisms made in the review of Volume I, hold equally well here. There are the same disregard of order, omission of definitions, and avoidance of scientific terms in common usage. It is quite consistent with this policy for the author, well on toward the end of Volume II, to state that "plus multiplied by plus produces plus," and to give the rule for squaring numbers, etc. The index is poor, and decidedly incomplete; the cuts are good, except in a few signal instances.

As to the scope of the work, it gives a fairly good idea of the compass as

[1] *A Treatise on Electro-Magnetic Phenomena, and on the Compass and its Deviations Aboard Ship, Mathematical, Theoretical, and Practical.* By COMMANDER T. A. LYONS, U. S. Navy. Vol. II.
The Compass and its Deviations. New York: John Wiley & Sons. 8 vo. pp. 557–1138. (The first volume was reviewed in this JOURNAL for October, 1901, p. 145.)

Digitized by Google

used in the U. S. Navy, though not a single good diagram or picture is shown of compass and compensating magnets in actual use. Is the same form of compass used by foreign nations? And on merchant vessels? Why does Kelvin's name receive such scant mention? These are among the questions that remain unanswered. No reason is apparent for not bringing the information down to date. Thus, on page 675, the magnetic elements at Washington are given for 1890; other similar instances might be quoted. Ether *waves*, properly speaking, are everywhere confused in a curious manner with magnetic fluctuations: on page 1114, "Chapter VII, intimately concerns the navigator; it relates to the great magnet—the Earth—to the surgings of its enveloping ether, as Variation, Dip, and Intensity."

Most readers will be surprised to learn that the Dip is "the maximum angle the direction of the dipping needle will make with the horizontal plane;" also that in magnetic calculations, l is the exact length of the magnet, from end to end. A few minor slips have been allowed to remain in the text, such as on page 985, where *dm* should be read for *mm*.

Part Third, "The Ship a Magnet," deserves much praise in spite of its defects. The experiments on the model vessel *Scoresby* are very interesting: the vessel was loaded with masses of iron, and pointed in different directions, and corresponding compass deviation curves are given, first with compass uncompensated, then under the influence of a compensating magnet. It is to be regretted that no curve is shown with the resultant effect of *all* compensating magnets when used at once. The introduction to the subject of sextantal deviations, etc., leaves much to be desired, but the example given, that of the U. S. S. *Ranger*, is excellent, showing a good agreement between theory and observation. The section on compensation of the deviations is also quite well given. A more careful discrimination might have been made between different methods, and a better description of apparatus in actual use, with drawings and dimensions, would have added to the value of the section.

The climax of the whole work is reached in the last part, "Various Matters Bearing on the Main Subject," which in many ways is a source of astonishment even to one familiar with all the preceeding pages. One paragraph is headed "Scales: Earth's Curvature: Duration of Light Flashes:" and these topics are disposed of in eight lines. A curious collection of references is appended in which no mention of the editions referred to is made. We note among other things, the omission of Nipher's "Magnetic Measurements." As an example of the author's inconsistency, the rather inadequate paragraph on the determination of H, is tacked on at the very end of the book.

We are tempted, in conclusion, to quote one or two statements that cast more light on the scientific value of the work, than many pages of criticism:

Page 677. "The azimuth circle.—A few words will suffice for this inseparable adjunct of the compass: every officer who uses it, knows the principles of its construction. It is made by Messrs. Ritchie; the material is brass, painted black, and it is inspected by the superintendent of compasses." Five lines concerning adjustments follow.

Page 842. "Rubbing the glass cover of the bowl with a silk or woolen cloth will excite electric currents in the glass which deflect the needle."

A. L. M.

Digitized by Google

AN INTRODUCTION TO PHYSICAL GEOGRAPHY.[1]

G. K. GILBERT AND A. P. BRIGHAM.

This book is designed for the use of pupils beginning the average American high-school course, and the reviewer has not met with any other text or reader which is so well adapted to the needs of that class of pupils. The accuracy of the statements is sufficiently vouched for by the positions held by the co-authors, both of whom have also repeatedly proved themselves excellent teachers.

The language and style have been most happily chosen. The sentences are short, simply constructed, and present clear-cut ideas. Constant, but natural reference to the relation of organic life and human history, to the physical features of the Earth, serves to heighten the reader's interest in the subject. Technical terms are not allowed to occur very often, and when they are used they are defined immediately.

The method of presenting the subject is that known as the "type method," each subject being introduced by the consideration of a type case; the discussion is then extended to include many excellently chosen examples under each type. The authors have not restricted themselves to any one land when looking for a type case, nevertheless, they seem to have found most of their types well represented in North America. Naturally, most of the examples are taken from American localities, since the text is designed for American schools.

The order of treatment and apportionment of space, is as follows:

The Earth and the Earth and Sun, 28 pages; The Lands, 195 pages; The Atmosphere, Weather, etc., 51 pages; The Earth's Magnetism, 5 pages; The Oceans, 23 pages; Shorelines, etc., 17 pages; Life, and the Earth, and Man, 52 pages. This distribution of attention seems quite proper for a book of this grade. The shortest chapter is the one on the Earth's Magnetism, but so clear is the language, that the fundamental truths about the compass, its declination, variation, and dip, are interestingly and sufficiently explained. A map of Isogonics for the United States in 1902, and one of the Magnetic Meridians for North America in 1885 accompany the section.

The use of 3-color contour maps in the text, well-chosen weather maps to illustrate a typical storm, the high character of the pictorial illustrations, and frequent cross-references, are features of special value in this book.

Washington, D. C., January 29, 1904. CLEVELAND ABBE, JR.

New York, D. Appleton & Co., 1904 (publ. 1002.) Size 7.5 inches x 5.25 inches, pp. xvi + 380.

Digitized by Google

LIST OF RECENT PUBLICATIONS
WITH BRIEF ABSTRACTS

BIGELOW, F. H. Eclipse Meteorology and Applied Problems. U. S. Weather Bureau. W. B., No. 267. Bulletin No. 1. Washington, 1902; 4°, 166 pp. [Chapters 1, 2, and 3, give an account of the observations by the U. S. Weather Bureau, made during the total eclipse of the Sun, May 28, 1900, at Newberry, South Carolina. Chapters 4 and 5 are concerned with the relations between solar and terrestrial meteorology.]

CREAK, E. W. Terrestrial Magnetism in its Relation to Geography. Address as Vice-President of Section E (Geography), British Assoc. Adv. Science. *Nature*, September 24, 1903. [A valuable and timely summary of the salient facts of the distribution of the Earth's magnetism and its secular variation, the conclusions drawn being very largely based on the author's extensive experience. The principal topics are: "Magnetic Surveys," "The Antarctic Expeditions," "The Magnetic Poles of the Earth," "The Secular Change," "Local Magnetic Disturbance," "Magnetic Shoals," "Terrestrial Magnetism and Geology," "Magnetic Charts and Portable Magnetic Instruments." In conclusion an appeal is made for observations in the regions where they are especially needed, e. g. at sea. The address has been reprinted in the London *Geographic Magazine* and in the *Scientific American Supp.* November 7, 1903.]

FINN, W. Influences of the Sun-spots upon Electrical and Magnetic Forces of the Earth. *Scientific American*, December 5, 1903, p. 2335. [Relates the chief results of his investigations of earth currents in telegraph lines.]

GÜNTHER, S. Das Polarlicht im Altertum. Repr. Gerland's Beitraege zur Geophysik, Bd VI, Heft. 1. Leipzig, 1903. 8° pp. 98–107. [The author concludes that the earliest reports of polar lights date from the Fourth Century B. C., believing that Aristotle's "Chasma" and Pytheas's "Meerlunge" can only be interpreted as referring to polar light phenomena. Other early references appear too doubtful. Reliable references are obtained again from Tacitus and Plutarch. The first thoroughly reliable observation in modern times is that by Konrad Gessner in 1561, as related in his "Historia," Zürich, 1561.]

HAMMER, W. J. Radium and other Radio-active Substances; Polonium, Actinium and Thorium, with a consideration of Phosphorescent and Fluorescent substances, the Properties and Applications of Selenium and the treatment of Disease by the Ultra-Violet Light. New York: D. van Nostrand Co. 1903. 8° 72. pp., 38 illustrations. Price $1. [A lecture delivered at a meeting of the Am. Inst. of Elect. Eng'rs and the Am. Electrochem. Soc., New York, April 17, 1903; the author has endeavored to exemplify by numerous experiments and illustrations the fundamental principles and phenomena of the subjects treated.]

Digitized by Google

NIPPOLDT, A. Erdmagnetismus, Erdstrom und Polarlicht. Leipzig. G. J. Göschen'sche Verlagshandlung, 1903. 12°, 136 pp., 3 pl. Price 80 Pf. [This excellent résumé of the fundamental facts and results of the latest investigations in terrestrial magnetism and its allied subjects forms No. 175 of the interesting *Sammlung Göschen*, each number of which is sold, bound in cloth, at the uniform price of 20 cents. While special stress is laid upon German contributions, the author exhibits a wide familiarity with and mastery of the contributions of other nations. Any one who has attempted to correlate, in an international spirit, the recent results of magnetic investigations will appreciate the difficulties of the author's task. For in a summary of this kind one can not content himself with published abstracts but must consult and master the originals, and that implies a familiarity with various languages and sciences.]

PALAZZO, L. Three reprints from "Protokoll über die dritte Versammlung der internationalen Kommission für wissenschaftliche Luftschiffahrt (Berlin 20-25 Mai, 1902.) Strassburg, Dumont-Schauberg, 1903.
Beilage 5. Die Theilnahme Italiens an der internationalen wissenschaftlichen Erforschung der hohen Atmosphäre. 2 pp.
Beilage 6. Die Einrichtung des neuen Observatoriums für die Physik der Atmosphäre auf dem Monte Rosa. 3 pp.
Beilage 19. Ueber ein registrirendes Elektrometer, welches auch für die Ballonfahrten oder Drachenaufstiege benutzt werden kann. 4 pp. [The author has adapted Exner's electroscope to photographic registration of potential differences and suggests modifications so that the photographic instrument could be used in balloon ascents, or with kites.]

ROOSENBURG, L. Der Platz für den Regelkompass. "De Zee," Aug. 1903, p. 339. [Translated from the Dutch into the German, by Dr. H. v. Hasenkamp, and published in Ann. d. Hydr. u. Maritimen Meterologie, 1903, Heft XII, Deutsche Seewarte, Hamburg. Pp. 555-560. Gives a brief statement of the fundamental principles to be observed in the placing of the standard compass on board ship.]

SCHMIDT, ADOLF. Aufgaben und Einrichtung eines erdmagnetischen Rechen-instituts. Versammlung Deutscher Naturforscher und Aerzte, Hamburg, 1901. Repr. 8°, pp. 191-194. [Abstract of an address on the problems and organization of a magnetic computing institute, which, while intended primarily for Germany, would also embrace in its scope problems of world-wide interest.]

SCHUSTER, A. Introductory Address as Chairman of Subsection, Cosmical Physics, Brit. Assoc. Adv. Science, 1902. Repr. 12°, 20 pp. [A discussion of the question: "If two events happen simultaneously, or one follows the other after a short interval of time, does this give any reason for supposing that the two events are connected with each other, both being due to the same cause, or one being the cause of the other?" As instances, are taken the investigation of the connection between Moon and earthquakes, and the connection between Sun-spots and rainfall. In conclusion the author dwells upon the necessity of reducing observations, and not merely piling them up or observing aimlessly.]

Digitized by Google

STARK, JOHANNES. Die Dissoziierung und Umwandlung Chemischer Atome. 8°, 58 pp. Braunschweig, Vieweg & Sohn. Price unb. 1.50 M. [A timely and excellent résumé of the results of the most recent investigations. Chapter 1 treats of electrical dissociation and conductivity in gases, electrolytes and metals; Chapter 2 is on the cause and nature of radioactivity according to the investigations of Rutherford and Soddy; Chapter 3 is a brief statement of the investigations by Rutherford and Soddy and Ramsay, on the evolution of helium from radium. In conclusion are given numerous notes and references. The author is privatdocent at the University of Göttingen.]

WAGNER, HERMANN. Peter Apian's Bestimmung der magnetischen Missweisung v. J. 1532 und die Nürnberger Kompass-macher. Nachr. d. K. Gesellsch. Wiss. Göttingen. Phil.-hist. Klasse, 1901. Heft. 2. 8°, 12 pp. [In Hellmann's article, "The Beginnings of Magnetic Observations," T. M., IV, p. 80, is given a tabulation of the values of the magnetic declination in the first half of the Sixteenth Century. Wagner shows that Apianus must be credited with a careful determination of the magnetic declination. Wagner's tabulation of the early values is as follows:

Year.	Place.	Magnetic Declination.	Observer or Authority.
1510±	Rome.	6° E.	Georg Hartmann.
1518±	Bay of Guinea.	(11¼ E.)	Piero di Giovanni d'Antonio di Dino.
1520±	Vienna.	4 E.	Joh. Georg Tannstetter (Rheticus).
1523 (?)	Landshut (?) (Bavaria).	9 E.	Petrus Apianus.
1532	Ingolstadt.	10½ E.	Petrus Apianus.
1534	Dieppe.	10 E.	François or Crignon.
1538	Nuremburg.	10¼ E.	Georg Hartmann.
1538	Lisbon.	7½ E.	Pedro Nunes or João de Castro.
1539±	Danzig.	13 E.	Georg Joachim Rheticus.
1541	Paris.	7 E.	Hieronymus Bellarmatus.
1544±	Nuremburg.	10 E.	Georg Hartmann.
1546±	Island Walcheren.	9 E.	Gerhard Mercator.

In the "United States Magnetic Declination Tables for 1902" is given a complete tabulation of all the magnetic declinations made on land prior to 1600, as far as they have become known.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

AUG 1 1940

Digitized by Google

Digitized by Google

AUG 2 7 1940

Digitized by Google